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# Recommendations for Interim Goals and Interim Targets for the Comprehensive Everglades Restoration Plan

# *Indicators and Prediction Methods*

**Prepared by**

## Restoration Coordination and Verification (RECOVER)

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# Recommendations for Interim Goals and Interim Targets for the Comprehensive Everglades Restoration Plan

# *INDICATORS AND PREDICTION METHODS*

### Technical Recommendations Prepared by RECOVER as per the CERP Programmatic Regulations

## Purpose of this Document

The purpose of this document is to provide the public and agencies with an opportunity to review the technical recommendations of the Restoration Coordination and Verification team (RECOVER) for the indicators that will be used to establish the initial set of Interim Goals and Interim Targets. This document also describes the process that was used by the RECOVER subteam that developed these recommendations. Interim Goals and Interim Targets will be used to assess the progress of the Comprehensive Everglades Restoration Plan (hereafter CERP or Plan) towards restoring the natural system and meeting other water-related objectives throughout implementation.

The indicator documentation sheets (Section 1 for Interim Goals, Section 2 for Interim Targets) provide information for each of the Interim Goal and Interim Target indicators, including a discussion of the justification and relevance of each indicator to the CERP and an explanation of how each of the goals and targets will be predicted and assessed. The actual numeric targets or trends for the proposed indicators have not yet been calculated. They will be calculated after the current indicators are reviewed and after the requisite computer simulation modeling is completed.

## Authority

Section 601(h) of Water Resources Development Act (WRDA) of 2000 (U.S. Congress 2000), the authorizing legislation for the CERP, represents the assurances provision for the implementation of the CERP and calls for Programmatic Regulations to be developed to ensure that the goals of the CERP are achieved. The final Programmatic Regulations for the CERP (DOD 2003) require the establishment of both Interim Goals to "provide a means by which the restoration success of the Plan may be evaluated throughout the implementation process" and Interim Targets for assessing progress towards meeting "other water-related needs."

## Definition and Description of Interim Goals and Interim Targets

Interim Goals are defined in the CERP Programmatic Regulations as "*a means by which the restoration success of the Plan may be evaluated throughout the implementation process*" (DOD 2003). Interim Goals provide a means of tracking restoration performance, as well as a basis for reporting on the progress made at specified intervals of time towards restoration of the South Florida ecosystem, and for periodically evaluating the accuracy of predictions of system responses to the effects of the Plan.

Interim Targets are defined as "*a means by which the success of the Plan in providing for other water-related needs of the region, including water supply and flood protection, may be evaluated throughout the implementation process*" (DOD 2003). Interim Targets provide a means of tracking Plan performance, as well as a basis for reporting on progress made at specified intervals of time towards providing for other water-related needs of the region, and for periodically evaluating the accuracy of predictions of system responses to the effects of the Plan.

## Process for Establishing Indicators for Interim Goals and Interim Targets

A RECOVER subteam developed a process in October 2002 for establishing Interim Goals and Interim Targets for indicators of ecosystem restoration and other water-related needs (Figure 1). Criteria were established by the RECOVER subteam to assist in the selection of indicators for Interim Goals and Interim Targets. The indicators should fulfill the following criteria:

1) Be consistent with the goals and purposes of the CERP
2) Address the physical and biological aspects of the Plan
3) Be consistent with the *CERP Monitoring and Assessment Plan* (RECOVER 2004) and the *CERP System-wide Performance Measures* (RECOVER in prep)
4) Be predictable and easily interpreted

In addition to these criteria, the RECOVER subteam also considered other factors including the following:

1) The need to maintain balance among physical stressor-based indicators and biological attribute-based indicators
2) The need to have indicators from all regions of South Florida affected by the Plan
3) The need to have enough indicators to adequately track representative responses for the major goals of the Plan without having so many as to be duplicative of the key goals
4) The need to have indicators that represent different response times (i.e., both short-term and long-term responses to the affects of CERP implementation)

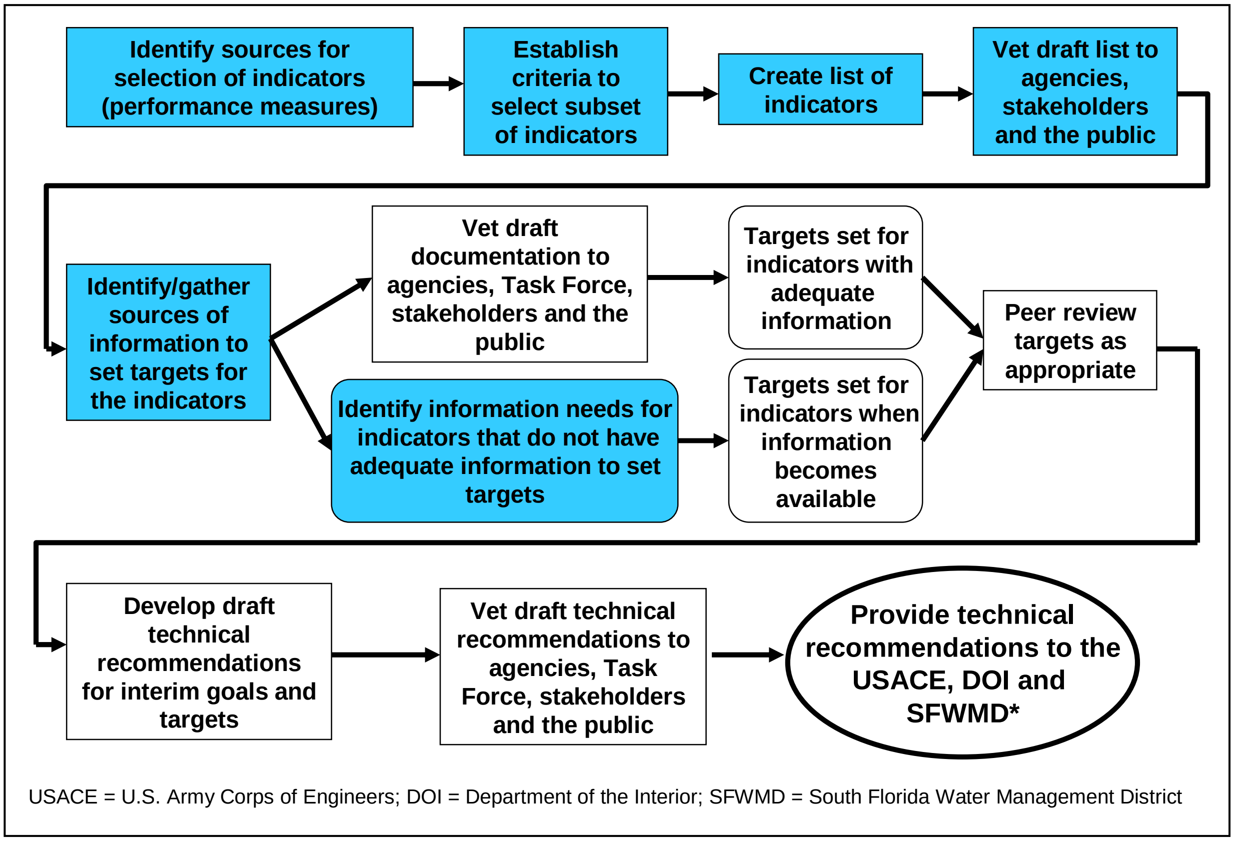


**Figure 1.** RECOVER process to provide technical recommendations in the establishment of Interim Goals and Interim Targets (shaded boxes represent efforts completed by RECOVER)

An initial recommendation for a set of indicators to represent the natural and human systems to be influenced by the CERP was proposed by the RECOVER subteam in February 2003 (RECOVER 2003). Indicators for Interim Goals were grouped as hydrologic, water quality and biological indicators. The initial recommendations for Interim Goals are presented in Table 1.

Indicators for Interim Targets address other water-related needs including flood protection and water supply and as such are hydrologic in nature. The initial recommendations for Interim Targets indicators are presented in Table 2 below. Other socio-economic goals of the CERP (e.g., recreation and navigation) may be considered for additional Interim Target indicators in future lists.

**Table 1.** Initial recommended list of indicators for Interim Goals for the Comprehensive Everglades Restoration Plan (as presented in RECOVER 2003)

| Title | Type | Applicable Region |
|---|---|---|
| Volume | Hydrology (Quantity and Distribution) | System-wide |
| Sheet Flow | Hydrology (Distribution) | Greater Everglades Wetlands |
| Hydroperiod | Hydrology (Timing and Distribution) | Greater Everglades Wetlands |
| Hydropattern | Hydrology (Distribution) | Greater Everglades Wetlands |
| Freshwater Inflows to Estuaries | Hydrology (Quantity and Timing) | Estuaries |
| Water Stages in Lake Okeechobee | Hydrology (Quantity) | Lake Okeechobee |
| Total Phosphorus | Water Quality | System-wide |
| Lake Okeechobee Phosphorus | Water Quality | Lake Okeechobee |
| Recovery of Threatened and Endangered Species and Supporting Habitats | Biological | System-wide |
| Wading Bird Nesting Patterns | Biological | System-wide |
| American Alligator Distribution and Abundance | Biological | System-wide |
| Periphyton Mat Cover, Structure and Composition | Biological | Greater Everglades Wetlands |
| Aquatic Fauna Regional Populations | Biological | Greater Everglades Wetlands |
| Ridge and Slough | Biological (Landscape) | Greater Everglades Wetlands |
| Everglades Tree Islands | Biological (Vegetation) | Greater Everglades Wetlands |
| Spatial Extent of Habitat Type | Biological (Landscape) | Greater Everglades Wetlands |
| Submerged Aquatic Vegetation in Estuaries | Biological (Vegetation) | Estuaries |
| American Oysters in Estuaries | Biological | Estuaries |
| Lake Okeechobee Ecological Communities | Biological | Lake Okeechobee |
| Lake Okeechobee Algal Blooms | Biological | Lake Okeechobee |
| Juvenile Pink Shrimp Density in Florida and Biscayne Bay | Biological | Southern Estuaries |

**Table 2.** Initial recommended list of Interim Targets for the Comprehensive Everglades Restoration Plan (as presented in RECOVER 2003)

| Title |
|---|
| Volume (Identical metrics as in Interim Goal for volume) |
| Water Supply for the Lower East Coast Service Area |
| Water Supply for the Lake Okeechobee Service Area |
| Prevention of Saltwater Intrusion of the Biscayne Aquifer |
| Flood Protection |

Each of the proposed indicators was assigned to an "organizer" with the appropriate expertise. The task of the organizer was to work within small technical teams to develop the method of prediction for the indicators and identify the process for setting numeric targets. A guidance document was prepared by the RECOVER subteam to assist each technical team in documenting the development of these numeric targets. The RECOVER subteam also developed a categorization process to assist the technical teams in defining the level of prediction for each of the indicators. These categories were further refined based on subteam discussions. The technical teams modified or added indicators, in an effort to provide more representative indicators or indicators that could be amenable to prediction at the present time. The work of the technical teams led to the revised list of indicators that are presented in this document. The process and schedule for producing the technical recommendations is provided in Figure 2.

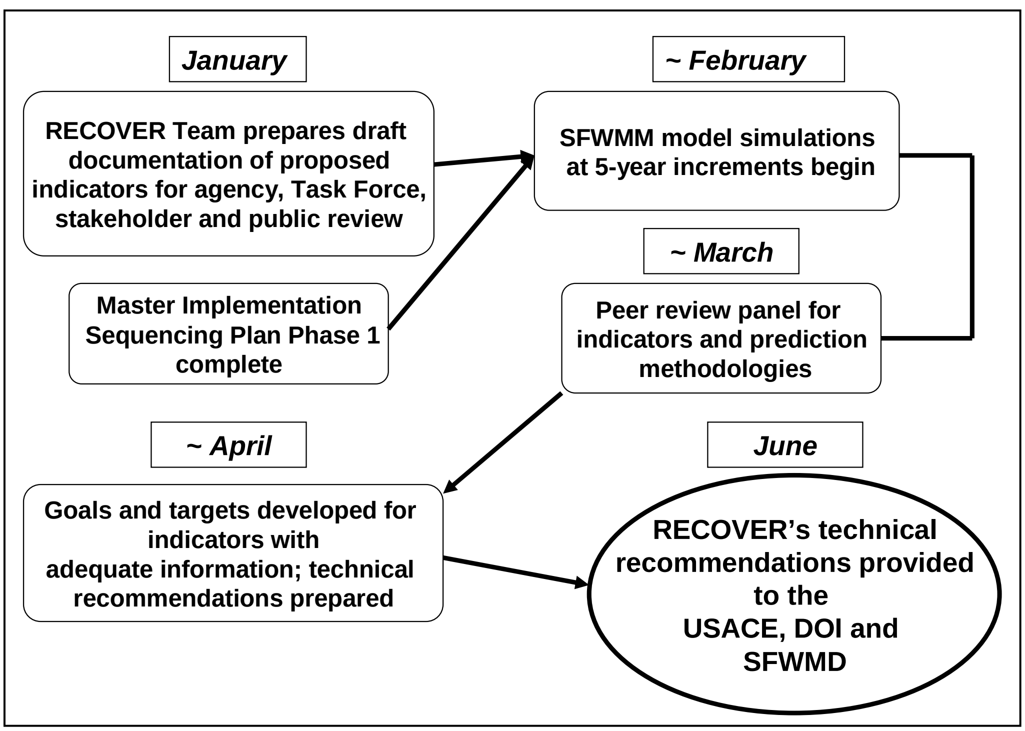


**Figure 2.** The process and schedule for producing RECOVER's technical recommendations to the U.S. Army Corps of Engineers (USACE), the Department of the Interior (DOI), and the South Florida Water Management District (SFWMD).

## Summary and Document Organization

Due to the importance placed on the Interim Goals and Interim Targets via legislative authority and regulation, the RECOVER subteam determined that the revisions to the indicators and the outlined prediction method for each should be vetted through a public and agency review process as well as be submitted to an independent peer review panel in Spring 2004. This current version of the document is being distributed for public and agency review.

The following sections of this document provide information on background and the status of each of the proposed indicators specific to Interim Goals (Section 1) and Interim Targets (Section 2). The current list of indicators for Interim Goals and Interim Targets can be found in each of their respective sections.

## References

DOD. 2003. Programmatic Regulations for the Comprehensive Everglades Restoration Plan; Final Rule. Department of Defense, 33 CFR Part 385, Federal Register, November 12, 2003.

RECOVER. 2003. Proposed Indicators for Interim Goals and Interim Targets for the Comprehensive Everglades Restoration Plan. Interim Goals and Interim Targets Subteam, Restoration Coordination and Verification, c/o South Florida Water Management District, West Palm Beach, Florida, Final Draft, February 19, 2003.

RECOVER. 2004. CERP Monitoring and Assessment Plan. Restoration Coordination and Verification, c/o United States Army Corps of Engineers, Jacksonville District, Jacksonville, Florida, and South Florida Water Management District, West Palm Beach, Florida.

RECOVER. In prep. CERP System-wide Performance Measures. Restoration Coordination and Verification, c/o South Florida Water Management District, West Palm Beach, Florida, and United States Army Corps of Engineers, Jacksonville District, Jacksonville, Florida.

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# Section 1. Interim Goals

## 1.1 Introduction

Interim Goals are defined in the CERP Programmatic Regulations as "*a means by which restoration success of the Plan may be evaluated throughout the implementation process*" (DOD 2003). Interim Goals provide a means for tracking restoration performance, for reporting on the progress made at specified intervals of time towards restoration of the South Florida ecosystem, and for periodically evaluating the accuracy of predictions of system responses to the effects of the Plan.

Indicators for Interim Goals were selected from a broad set of stressors and attributes found in the set of South Florida conceptual ecological models that are described in Appendix A of the *CERP Monitoring and Assessment Plan* (RECOVER 2004). Each regional conceptual ecological model identifies the major hydrologic and chemical stressors in a landscape type within South Florida (e.g., St. Lucie Estuary, Everglades Ridge and Slough) and documents the known effects of these stressors on a set of biological attributes. Because the CERP will modify hydrology and water quality (stressors) that affect biological communities in the South Florida ecosystem (attributes), indicators that pertain to each ecological region were included for both stressors and attributes. In addition, indicators that represented short-term, intermediate, and long-term responses were chosen based on the variable response time of biological communities to changes in hydrology and water quality. Interim Goals indicators can be identified as hydrologic and chemical stressors and biological attributes (Figure 3).

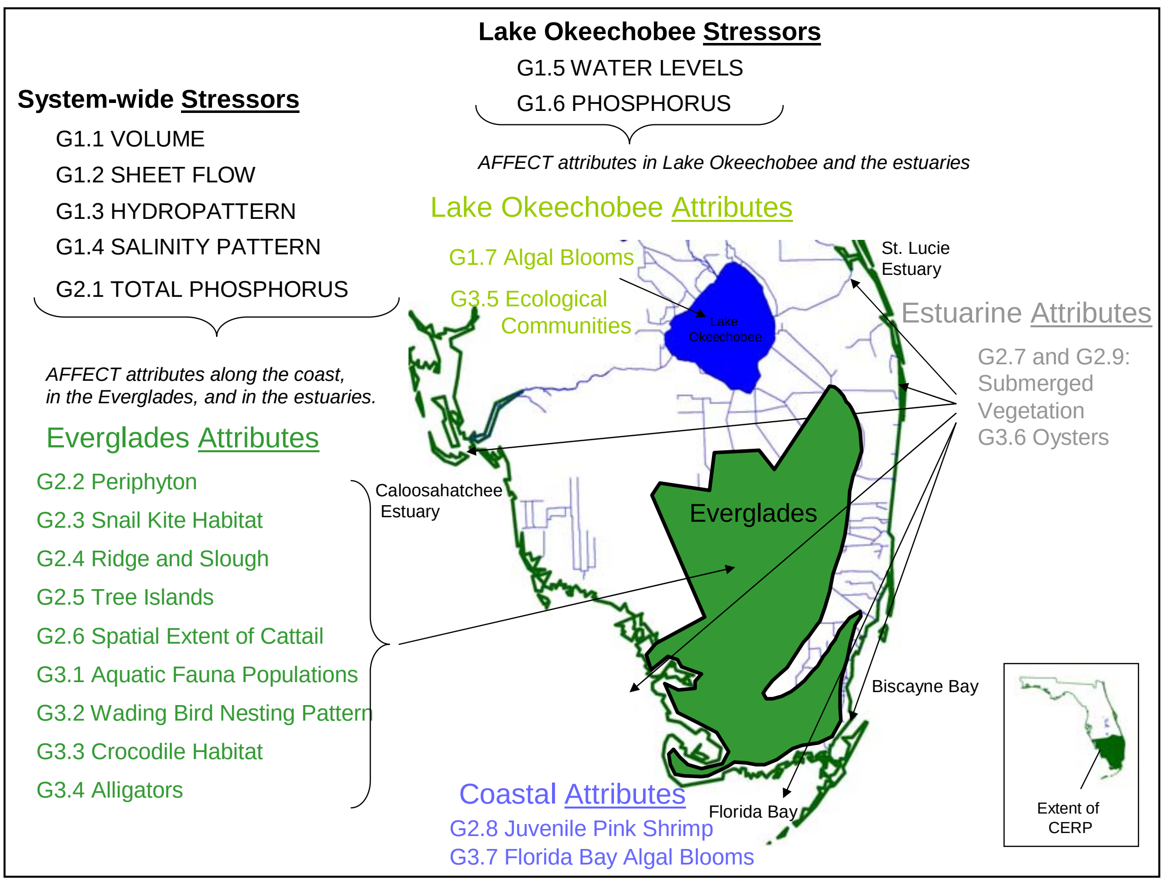


**Figure 3.** Hydrologic and chemical stressors and biological attributes used as indicators for Interim Goals

Generally, indicators that are considered stressors are grouped as both system-wide stressors and those that exert a large effect on Lake Okeechobee. Indicators that are considered biological attributes are represented for Lake Okeechobee, the Greater Everglades Wetlands south to Florida Bay, the estuaries, and coastal areas.

## 1.2 How Predictions Will Be Made for Interim Goals

Many of the indicators will use numerical or computational models as tools to predict how the indicators will respond to changes brought about by the CERP. By modeling the indicators at discrete time intervals, an expected level of performance can be predicted and performance milestones can be established throughout the life of the Plan. The process of developing Interim Goals will result in some measurable parameters that can be evaluated by a numeric target (e.g., hydrological responses). Predicting the outcome of some indicators (i.e., the biological indicators) is expected to have an inherent level of uncertainty (see Section 1.3) because current understandings of ecological relationships are incomplete, and the ecological models used to predict biological responses are in various stages of development and review. Predictive models are not available for other indicators and the prediction of numeric goals may not be possible for several years, although trends (i.e., directions of change) can be predicted.

The South Florida Water Management Model (SFWMM) is the primary hydrologic simulation model that will be used in the prediction of Interim Goals. The SFWMM is used to predict goals directly or it may provide boundary conditions, or hydrologic inputs, to other subregional hydrologic or ecologic and water quality models that will be used to assist in this effort. The SFWMM is a regional-scale computer model that simulates the hydrology and the management of the water resources system from Lake Okeechobee to Florida Bay. It covers an area of 7,600 square miles using a mesh of 2-mile x 2-mile cells. The model includes inflows from the Kissimmee River, and both runoff and demands in the Caloosahatchee River and St. Lucie Canal basins. The SFWMM simulates the major components of the hydrologic cycle in South Florida including rainfall, evapotranspiration, infiltration, overland and groundwater flow, canal flow, canal-groundwater seepage, levee seepage and groundwater pumping. It incorporates current or proposed water management control structures and current or proposed operational rules.

The model requires input data, termed “assumptions”, that govern the outputs, or results, of a given model simulation. Many types of data are needed to run the model, including the following:

- Topography (ground elevation data)
- Rainfall
- Evapotranspiration rates
- Sea level data
- Land use
- Vegetation types
- Irrigation and agricultural demands
- Municipal and industrial water supply demands
- Central and Southern Florida (C&SF) Project water management system structures, operational rules, regulations and schedules
- Canal stages and flows

The SFWMM will simulate conditions predicted for the South Florida ecosystem at five-year increments. The first five-year increment begins in 2005-2010 with results predicted for 2010. Results will also be predicted for the five-year increments ending in 2010, 2015, 2020, etc., until 2050. Based upon the *Master Implementation Sequencing Plan* (USACE and SFWMD 2004), CERP components expected to be completed within each increment will be added as input data to the model. In this manner, as each five-year increment is evaluated, predictions (numeric targets) of the progress of the CERP towards meeting restoration goals may be established.

## 1.3 How Does Uncertainty Affect the Use and Assessment of Interim Goals?

The RECOVER team recognizes that there are several sources of uncertainty associated with the process of developing, predicting and interpreting Interim Goals. In general, these uncertainties can be grouped into four types, each of which is capable of influencing any prediction. Uncertainties are associated with 1) modeling, 2) scheduling of CERP projects, 3) environmental variability and 4) geo-political change.

### *Model Uncertainty*

All model outputs contain some level of uncertainty or variability (defined as deviations from actual or expected values of predictions). Physical and biological models may contain uncertainty resulting from an incomplete understanding and representation of major processes (Gross and Comiskey 2003). Landscape models contain uncertainty associated with incomplete data and the complexity of the landscape. Uncertainties can also result from imprecise measurements of important physical and biological parameters used in equations that describe processes or initial conditions. In general, the more complex the model structure, the greater the total variation of both observational and simulated data and the less accurate (more uncertain) the prediction (Costanza and Sklar 1985). The degree of uncertainty, accuracy and calibration extent of all the models used to predict Interim Goals will be evaluated according to the criteria that was discussed in the Modeling Uncertainty Report provided to the South Florida Water Management District by Loucks and Stedinger in 1994.

### *CERP Scheduling*

The uncertainties associated with the CERP schedule may include unanticipated legal constraints and lawsuits, construction delays, contractual bottlenecks associated with land purchases, feasibility studies and new technologies, adjustments in schedule brought about by the adaptive management process, and the overall complexity associated with the management of a very large restoration program.

The Interim Goals will assume a particular sequence of CERP projects as defined in the *Master Implementation Sequencing Plan* (USACE and SFWMD 2004), as well as a construction period for each project and a specific “benefit” associated with each project. A change in any one of these three assumptions can alter the timing and effectiveness of restoration. Unfortunately, it is unknown just how indicator performance will respond when sequencing is altered. Any schedule change to a CERP or non-CERP project that is directly influencing the volume, flows or quality of the water to the South Florida ecosystem may noticeably alter any predictions associated with hydrologic and water quality goals and targets. Schedule shifts may also noticeably alter predictions associated with the biological and ecological goals.

### *Environmental Variability*

Interim Goals will assume a particular weather and rainfall pattern when using simulation models. Any changes in climate or climatic variability, sea level, and hurricane frequencies may result in major differences between model predictions based on 1965-2000 conditions and the conditions that actually occur in the future. To account for this uncertainty, in the future all the models used to predict the Interim Goals with the expected time increments of the Plan will be rerun every five years with the real, updated weather and rainfall data. These revised milestones for Interim Goals will then be compared with actual observations to see if the ecosystem is responding as expected and to make sure that restoration is proceeding in the appropriate direction.

### *Geo-political Change*

Large-scale economic, social or geo-political events may influence large-scale projects such as the CERP as state and federal priorities shift in response to these events. These shifting priorities may present themselves as changes in resource allocations or in the scope of the CERP. Of all the uncertainties, geo-political change is the most unknowable. In the implementation planning process for the CERP and the establishment of Interim Goals, however, we must assume geo-political stability.

## 1.4 How the Interim Goals Will Be Approved

According to the Programmatic Regulations (DOD 2003), RECOVER will provide its recommendations to the U.S. Army Corps of Engineers, the Department of the Interior and the South Florida Water Management District by June 14, 2004. In consideration of these recommendations, the Secretary of the Army, Secretary of the Interior and the Governor will develop an Interim Goals Agreement in consultation with other governmental bodies.

## 1.5 How the Interim Goals Will Be Revised

As stated in the Programmatic Regulations (DOD 2003), the agreed upon Interim Goals will be reviewed at least every five years to determine if they should be revised. Any revisions will undergo the same development and agreement process as the initial Interim Goals. Revisions will incorporate new information, improved prediction capabilities, and improved understanding of the ecosystem and its relationships, resulting in a set of goals that improve over time and a refinement of the expected benefits of the Plan. New information will become available as annual monitoring data are accumulated. Studies of the linkages between climate variables, hydrology, water quality and biological responses will increase the understanding of ecosystem processes. This improved understanding combined with observations of specific project effects will enable more accurate predictions of ecosystem response. More appropriate indicators of ecosystem restoration may be identified and may be added to or substituted for current indicators. The models and other tools used to predict success of the Plan will become more accurate as a direct result of improved understanding of the ecosystem. Ecological and water quality models will provide alternative prediction methods. In addition, advances in computer hardware will allow for greater spatial resolution and will provide for the development of more accurate (i.e., more powerful) models. Revisions will also be made in response to other changes including changes in implementation sequencing, changes in the design and operation of the Plan, and changes resulting from adaptive management.

## 1.6 Status of the Proposed Indicators for Interim Goals

The indicators shown in Table 3 represents the current list of indicators and is organized into groups as described below. This grouping is not intended to reflect a separation of importance for the Interim Goals, but rather provides a means to distinguish between indicators that will require additional effort in developing an Interim Goal that provides the milestones or a quantifiable basis for evaluating the restoration success of the CERP as stated in the Programmatic Regulations (DOD 2003). This grouping reflects the current state of the prediction methodology for these indicators. Indicators may be grouped differently as new information and refinements to current models are developed. It is anticipated that recognition of the status of indicators in groups 2 and 3 will stimulate action to develop and/or complete the predictive tools needed for these indicators.

**Table 3.** List of recommended Comprehensive Everglades Restoration Plan Interim Goal indicators by group

| |
|---|
| **Group 1:** Indicators that will be developed into Interim Goals using established predictive methods |
| G1.1 Volume – Quantity and Distribution |
| G1.2 Sheet Flow in Greater Everglades Wetlands |
| G1.3 Hydropattern in Greater Everglades Wetlands |
| G1.4 Salinity Patterns in Florida and Biscayne Bays |
| G1.5 Water Levels in Lake Okeechobee |
| G1.6 Lake Okeechobee Phosphorus |
| G1.7 Lake Okeechobee Algal Blooms |
| **Group 2:** Indicators that will be developed into Interim Goals, although the predictive tools are still under development and/or review |
| G2.1 Greater Everglades Wetlands Total Phosphorus |
| G2.2 Periphyton Mat Cover, Structure and Composition |
| G2.3 Recovery of Threatened and Endangered Species and Supporting Habitats - Snail Kite |
| G2.4 Ridge and Slough Pattern |
| G2.5 Everglades Tree Islands |
| G2.6 Spatial Extent of Cattail Habitat |
| G2.7 Submerged Aquatic Vegetation in Southern Estuaries |
| G2.8 Juvenile Pink Shrimp Densities in Florida and Biscayne Bays |
| G2.9 Submerged Aquatic Vegetation in Northern Estuaries |
| **Group 3:** Indicators that, at present, cannot be developed into Interim Goals, although progress will be reported to Congress at five-year intervals, and for which predictive methods will be developed |
| G3.1 Aquatic Fauna Regional Populations in Greater Everglades Wetlands |
| G3.2 System-wide Wading Bird Nesting Patterns |
| G3.3 Recovery of Threatened and Endangered Species and Supporting Habitats - American Crocodile |
| G3.4 System-wide American Alligator Distribution and Abundance |
| G3.5 Lake Okeechobee Ecological Communities – Submerged Aquatic Vegetation |
| G3.6 American Oysters in Estuaries |
| G3.7 Florida Bay Algal Blooms |

## 1.7 References

Costanza, R., and F.H. Sklar. 1985. Articulation, accuracy, and effectiveness of mathematical models: a review of freshwater wetland applications. Ecol. Model. 27:45-68.

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Loucks, D.P., and J.R. Stedinger. 1994. Sensitivity and Uncertainty Analysis in Hydrologic Simulation Modeling of the South Florida Water Management District. Report of the Workshop on Reduction of Uncertainties in Regional Hydrologic Simulation Models. School of Civil and Environmental Engineering, Cornell University, Ithaca, New York.

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USACE and SFWMD. 2004. Master Implementation Sequencing Plan. United States Army Corps of Engineers, Jacksonville District, Jacksonville, Florida, and South Florida Water Management District, West Palm Beach, Florida.

## 1.8 Indicator Documentation Sheets

The following pages contain the indicator documentation sheets for Interim Goals.

# INDICATOR G1.1 – WATER VOLUME – QUANTITY AND DISTRIBUTION

Please note that this indicator has both and interim goal and interim target associated with it. The Interim Target indicator (T1.1) is presented in Section 2.

## What is the restoration goal?

The restoration goals for water quantity and distribution are as follows:

**Total System Water Distribution:** Provide more natural water volume deliveries to the natural areas while providing for the other water-related needs of the region.

**New Available Water:** Provide the volume of water to the natural system that is needed to meet the hydrological restoration goals in each region while providing for other water-related needs.

## Why is this indicator important?

Ecosystem benefits depend on the improvement of water quantity, quality, timing and distribution. The increase in regional storage capacity provided by the CERP will make these hydrologic improvements possible while providing for other water water-related needs by increasing the available source of water.

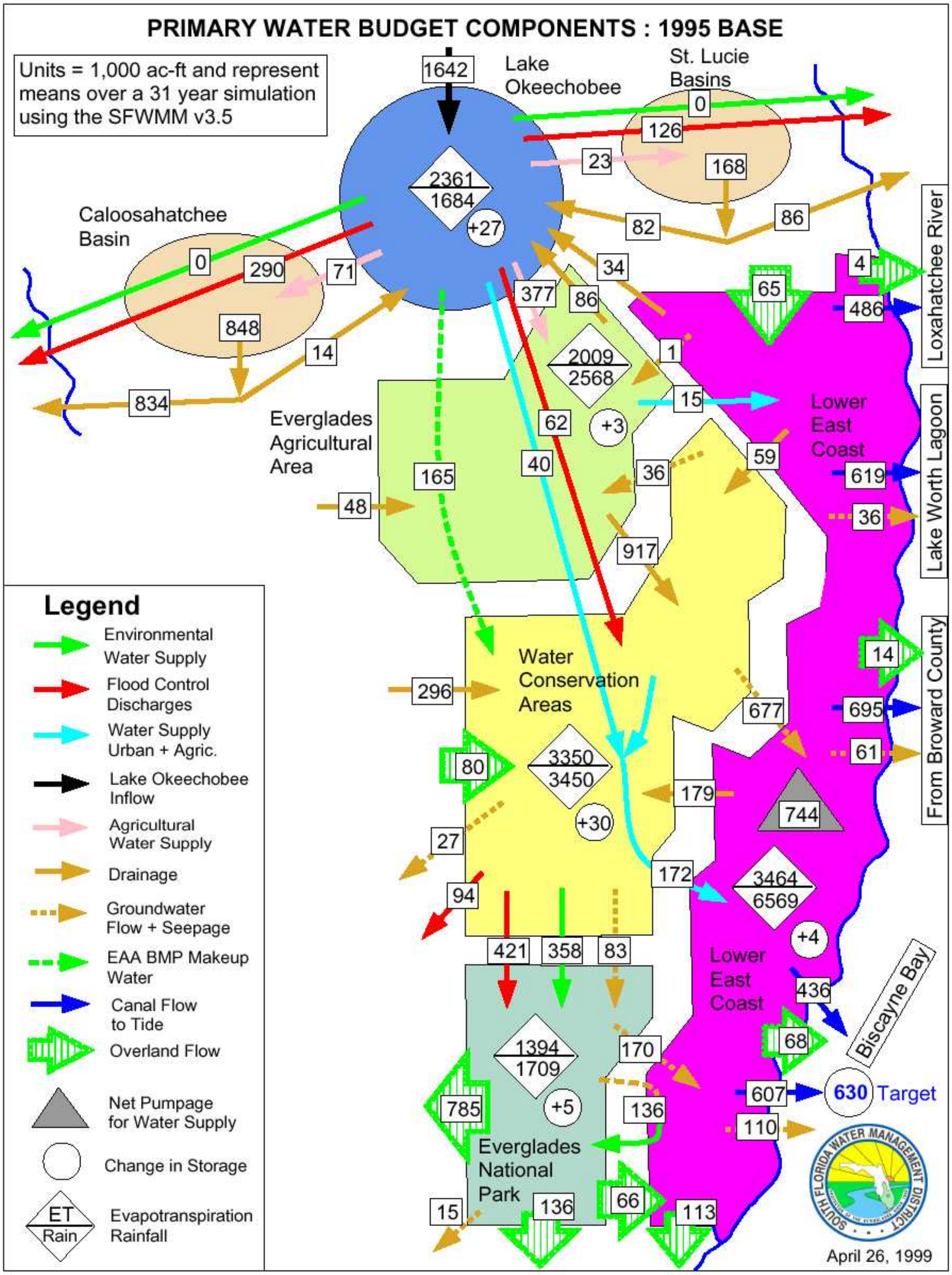
## How will the interim goal for this indicator be predicted?

This goal is based on South Florida Water Management Model (SFWMM) system-wide water budgets that track water distribution. Using the budgets to set goals provides each region (and, indirectly, many interests) with a set of mutually consistent expectations. In recognition of this, the water budget is used as an interim goal. The water budget quantifies the water distribution to basins containing urban and agricultural land uses, and protected natural areas. The Total System Water Distribution goal provides the bulk quantity of water distributed throughout the system and the New Available Water goal represents the distribution of the portion of that water that is made available by the CERP.

**Total System Distribution:** This part of the water volume indicator will be used to predict the quantity of water distributed to the natural system in average annual wet season and dry season deliveries. Water budgets provide an excellent way to account for broad changes in water distribution through plan implementation.

Water budget maps based on structure flow data, overland flow, and groundwater flow predicted by the SFWMM will be used to predict the quantity of water distributed within the region. The maps are divided into 11 basins: Kissimmee, Lake Okeechobee, Caloosahatchee Canal basin, St. Lucie Canal basin, Everglades Agricultural Area, Water Conservation Areas, Lower East Coast Service Areas, Everglades National Park, basin west of Everglades Agricultural Area and Water Conservation Area 3A, Florida Bay, and Biscayne Bay. Figure 4 presents an **example** of a water budget map. This map is based on the Base 95 Simulation conducted during the C&SF Project Comprehensive Review Study, known as the Restudy, that resulted in the development of the CERP (USACE and SFWMD 1999).

For the interim goal calculation, the Water Conservation Areas will be treated as separate basins, unlike the following example. Releases to tide from these basins are given separately for St. Lucie Estuary, Caloosahatchee Estuary, Loxahatchee River, Lake Worth Lagoon, Broward coast, Biscayne Bay and Florida Bay. Net water movement between the basins and from the basins to tide is tracked and identified by arrows on the map; changes in storage are also reported. The distribution of water to and from each basin will be documented by the SFWMM water budget map for each interim year.




1 **Figure 4.** An example of a water budget map based on the Restudy Base 95 simulation (the actual interim target calculation will treat each water conservation area as a separate area)

**New Available Water:** This part of the water volume indicator will predict the increase in volume of water over 2000 existing condition quantities that are available to benefit urban and agricultural users and natural system functions as a result of the CERP. This "new available water" will also be based on the water budget maps, but the calculation is taken one step further by calculating the difference in volumes for a given basin between the interim date and 2000 and posting that quantity as the goal for the interim date.

A more detailed description of this calculation involves a matrix used to summarize inflows and outflows to and from each basin for any given simulation. Table 4 provides an **example** of this matrix. The balance of inflows and outflows is compared between two simulations to provide the increase or decrease in storage within a basin (an **example** is provided in Table 5). For instance, the interim goal might be set as an increase in storage of X acre-feet (ac-ft) from 2000 to 2015 in the Everglades Agricultural Area. In this way, incremental steps toward Plan implementation can be tracked through the interim model simulations. Any increases in storage represent "new available water" provided by one simulation over another by redistributing the water in the system. The sum of the changes in storage must always be zero; some basins show a loss of storage while others show a gain. Generally, interior basins show increases and estuaries show losses indicating the flood releases that the CERP captures. The indicator will treat the Water Conservation Areas separately, though they are shown as one basin in these example tables.

### How will we track whether the goals established for the indicator have been achieved?

Field observations of stage and structure flow can be used to determine whether the actual distribution of water matches the predicted distribution of water. In order to provide a more complete analysis of water distribution in terms of interannual variability, the regional model will be used to simulate the projects as they were actually constructed. Water budgets will be recalculated to further determine the extent to which the Plan is meeting expectations.

### What additional work is needed to improve this interim goal?

As the regional hydrologic models are improved, this goal will be revised.

**Table 4.** An example of a water budget matrix based on the 1995 Base inflows and outflows from each basin (the actual interim target calculation will treat each water conservation area as a separate basin)

| | | Outflows From | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Kissimmee | Lake Okeechobee | Everglades Agricultural Area | Water Conservation Areas | Lower East Coast | Everglades National Park | West of Everglades Agricultural Area and Water Conservation 3A | Caloosahatchee | St. Lucie | Everglades Agricultural Area Reservoirs | Caloosahatchee Reservoirs | St. Lucie Reservoirs | Lake Okeechobee Reservoirs | Lower East Coast ASR | Lower East Coast Reuse | North Reservoirs | **Total Inflows** | **Balance (inflows-outflows)** |
| **Inflows To** | Kissimmee | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -1642 |
| | Lake Okeechobee | 1642 | 0 | 86 | 0 | 0 | 0 | 0 | 14 | 82 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1824 | 670 |
| | Everglades Agricultural Area | 0 | 377 | 0 | 36 | 0 | 0 | 48 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 461 | -542 |
| | Water Conservation Areas | 0 | 267 | 917 | 0 | 238 | 0 | 376 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1798 | -70 |
| | Lower East Coast | 0 | 0 | 0 | 849 | 0 | 236 | 0 | 0 | 65 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1150 | -2407 |
| | Everglades National Park | 0 | 0 | 0 | 862 | 70 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 932 | -240 |
| | West of Everglades Agricultural Area and Water Conservation Area 3A | 0 | 0 | 0 | 121 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 121 | -303 |
| | Caloosahatchee Canal | 0 | 71 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 71 | -777 |
| | St. Lucie Canal | 0 | 23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 23 | -210 |
| | Florida Bay | 0 | 0 | 0 | 0 | 113 | 936 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1049 | 1049 |
| | Biscayne Bay | 0 | 0 | 0 | 0 | 1221 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1221 | 1221 |
| | Caloosahatchee Canal to Tide | 0 | 290 | 0 | 0 | 0 | 0 | 0 | 834 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1124 | 1124 |
| | St. Lucie Canal to Tide | 0 | 126 | 0 | 0 | 0 | 0 | 0 | 0 | 86 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 212 | 212 |
| | Palm Beach/Broward to Tide | 0 | 0 | 0 | 0 | 1915 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1915 | 1915 |
| | Everglades Agricultural Area Reservoirs | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Caloosahatchee Reservoirs | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | St. Lucie Reservoirs | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Lake Okeechobee Aquifer Storage and Recovery (ASR) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Lower East Coast ASR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Lower East Coast Reuse | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | North Reservoirs | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Total Outflows** | | 1642 | 1154 | 1003 | 1868 | 3557 | 1172 | 424 | 848 | 233 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11901 | |

**Table 5.** An example of calculation to determine the change in storage within each basin based on the Restudy Base 95 simulation (the actual interim target calculation will treat each water conservation area as a separate basin)

| Basin | 1995 | Full CERP Performance | Change in Storage |
|---|---|---|---|
| Kissimmee | -1,640 | -1,540 | 100 |
| Lake Okeechobee | 670 | 730 | 60 |
| Everglades Agricultural Area | -540 | -440 | 100 |
| Water Conservation Areas | -70 | -100 | -30 |
| Lower East Coast Service Areas | -2,400 | -2,010 | 390 |
| Everglades National Park | -240 | -210 | 30 |
| West of Everglades Agricultural Area and Water Conservation Area 3A | -300 | -270 | 30 |
| Caloosahatchee Canal | -780 | -770 | 10 |
| St. Lucie Canal | -210 | -670 | -460 |
| Florida Bay | 1,050 | 1,350 | 300 |
| Biscayne Bay | 1,220 | 1,070 | -150 |
| Caloosahatchee Canal to Tide | 1,120 | 570 | -550 |
| St. Lucie Canal to Tide | 210 | 560 | 350 |
| Palm Beach/Broward Coast to Tide | 1,920 | 1,480 | -440 |
| Everglades Agricultural Area Reservoirs | 0 | 30 | 30 |
| Caloosahatchee Reservoirs | 0 | 140 | 140 |
| St. Lucie Reservoirs | 0 | 10 | 10 |
| Lake Okeechobee ASR | 0 | 130 | 130 |
| Lower East Coast ASR | 0 | 130 | 130 |
| Lower East Coast Reuse | 0 | -260 | -260 |
| North Reservoirs | 0 | 80 | 80 |

## References

USACE and SFWMD. 1999. Central and Southern Florida Project Comprehensive Review Study Final Integrated Feasibility Report and Programmatic Environmental Impact Statement. United States Army Corps of Engineers, Jacksonville District, Jacksonville, Florida, and South Florida Water Management District, West Palm Beach, Florida.

# INDICATOR G1.2 – SHEET FLOW IN THE GREATER EVERGLADES WETLANDS

## What is the restoration goal?

The restoration goal for sheet flow is to establish a more historic pattern of directionality of water movement in the natural areas of the greater Everglades.

## Why is this indicator important?

Broad, uninterrupted overland flow (sheet flow) was a predrainage characteristic of the Everglades slough landscape (Science Coordination Team 2003). The implementation of the CERP is expected to improve the pattern of this characteristic flow regime by modifying timing and spatial distribution throughout the region and by eliminating unnatural barriers to overland flow.

## How will the interim goal for this indicator be predicted?

The South Florida Water Management Model (SFWMM) provides a flow vector (magnitude and direction) for each cell in the protected area (including Water Conservation Areas 1, 2, 3A and 3B, and Everglades National Park). When mapped, this vector field represents the movement of water over the landscape. Vector maps will be produced for average annual wet season and dry season flows for each simulated interim date. While both magnitude and direction will be predicted and presented, only the directional component of the vector will be considered the interim goal at this time.

To help interpret the vector field maps, the direction of water movement within each cell (measured in degrees from a reference) will be compared to the predicted direction for the same cell under the CERP (or the currently authorized plan). The background color of each cell will reflect the difference between the interim simulation and the authorized plan (in degrees) and will provide an illustration of cells that have already met their full performance level and those that are expected to continue to improve at each interval.

## How will we track whether the goals established for this indicator have been achieved?

A comprehensive field-monitoring program for flow direction would be costly and time consuming. However, some elements of the *CERP Monitoring and Assessment Plan* (RECOVER, 2004) may provide data that can be used to determine whether or not this directional interim goal is met. It is likely that simulations at five-year increments including all projects implemented at that date will also be used to determine whether the combination of constructed projects is producing the predicted sheet flow directionality.

## What additional work is needed to improve this interim goal?

As regional hydrologic models are improved, this interim goal will be revised. As proposed, the interim goal is focused on the directionality of water movement not its velocity. With improvements in our predictive tools and ecosystem understanding, it may be possible to predict expected improvements in water velocity in addition to the directional goal proposed here.

## References

RECOVER. 2004. CERP Monitoring and Assessment Plan. Restoration Coordination and Verification, c/o Jacksonville District, United States Army Corps of Engineers, Jacksonville, Florida, and South Florida Water Management District, West Palm Beach, Florida.

Science Coordination Team. 2003. The Role of Flow in the Everglades Ridge and Slough Landscape. South Florida Ecosystem Restoration Working Group, Miami, Florida.

# INDICATOR G1.3 – HYDROPATTERN IN THE GREATER EVERGLADES WETLANDS

## What is the restoration goal?

The restoration goal for hydropattern is to restore natural seasonal inundation throughout the system in order to provide more natural hydropatterns for South Florida ecological communities.

## Why is this indicator important?

The annual duration of land surface inundation (hydroperiod) determines in large part the flora and fauna associated with a specific location. Because of this strong linkage, hydroperiod is an important indicator of a functioning ecosystem. Implementation of CERP components is expected to improve the spatial distribution of hydroperiods by modifying the water management system to approach more natural hydropatterns under which native flora and fauna communities were established and sustained.

## How will the interim goal for this indicator be predicted?

The South Florida Water Management Model (SFWMM) predicts stages (water level) daily in every cell. This data, combined with ground surface elevation, can be used to predict inundation (water above the land surface). The percent of each of these landscapes inundated in each month can be calculated as an indicator and has been called pond count statistics.

Pond count statistics aggregate the spatial extent of ponding for a particular landscape. Each day, the number of SFWMM 2- by 2-mile cells that are "inundated" are counted to produce a daily time series of the percentage of the landscape that is inundated.

For example, in the wet season month of October, we might expect 100 percent of the ridge and slough landscape to be inundated, while in the dry season month of May, less than 100 percent of the ridge and slough landscape may be inundated. When this data is plotted over a year, the area of inundated land surface is smaller in the dry season and expands as a result of the rains of the wet season. (Figure 5)

Since seasonal inundation patterns are expected to be unique for each landscape and to respond differently to CERP implementation, this calculation would be performed for the ridge and slough landscape in the remnant Everglades as well as for the eastern and western marl prairies in the southern Everglades. Also, because the inundation patterns are so dependent on the interannual variability in rainfall, graphs will be produced for a wet year (1995) and a dry year (1989), in addition to an average of the period of record of the model.

Data for the existing condition and each of the interim years can be presented together on one graph to show the trends approaching full comprehensive plan implementation through time (Figure 5). Additional examples of this method can be viewed at the following web site.

http://www.sfwmd.gov/org/pld/restudy/hpm/frame1/maps/pondcount.htm.

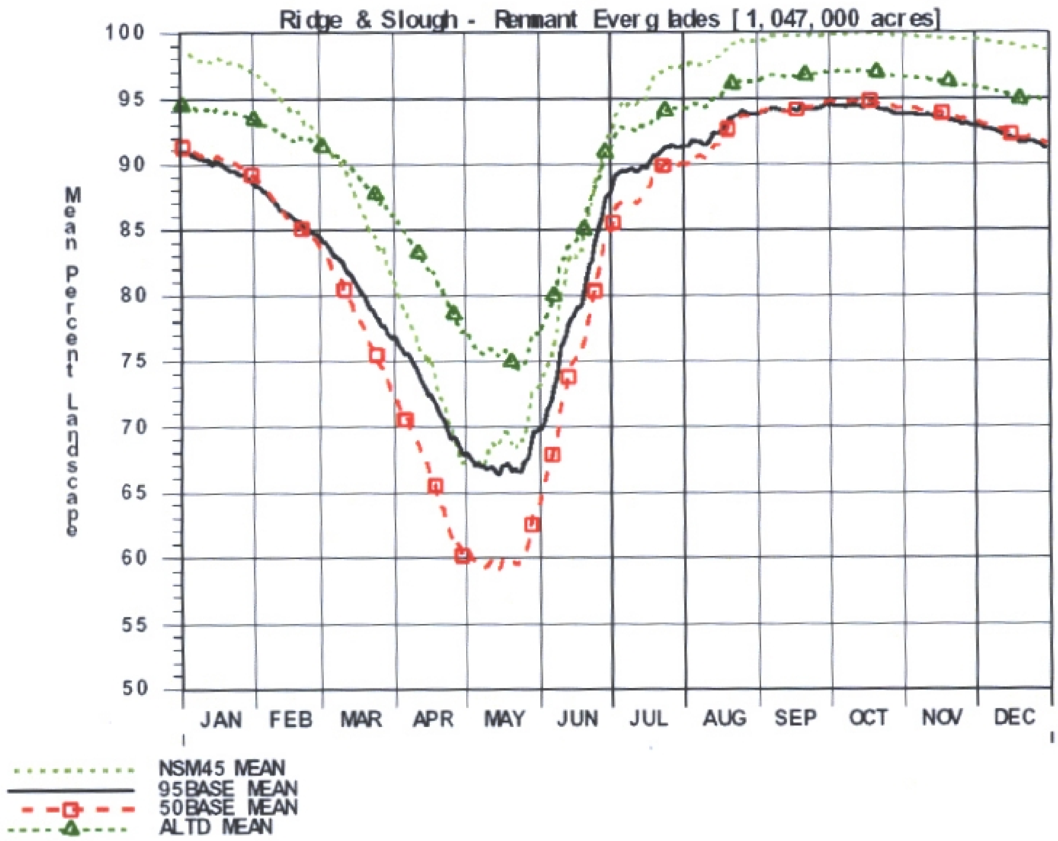



**Figure 5.** Mean percent landscape inundated in the ridge and slough from January through December

### How will we determine whether the goals established for this indicator have been achieved?

Field observations of stage can be used to determine whether or not the landscape is inundated at the spatial extent and for the duration of time predicted. In order to provide a more complete analysis of inundation in terms of interannual variability, the regional model will be used to simulate the projects as they were actually constructed. Inundation will be recalculated to further determine the extent to which the Plan is meeting expectations.

### What additional work is needed to improve this interim goal?

This interim goal will be revised as the regional hydrologic models are improved.

# INDICATOR G1.4 - SALINITY PATTERNS IN FLORIDA AND BISCAYNE BAYS

## What is the restoration goal?

The restoration goal for salinity patterns in estuaries is reduce the intensity, frequency, duration, and spatial extent of hypersaline events, reestablish common mesohaline conditions in mainland nearshore zones, and reduce the frequency and rapidity of salinity fluctuations derived from pulse releases of freshwater from canals.

## Why is this indicator important?

The estuarine environment is sensitive to freshwater inputs. Modifications of the volume, distribution, circulation or temporal patterns of freshwater discharges can place severe stress upon the ecosystem. Salinity patterns affect productivity, population distribution, community composition, predator-prey relationships and food web structure in coastal waters and adjacent wetlands. The salinity patterns of South Florida's estuaries have been radically altered in time and space by water management structures and operations. One CERP objective is to restore the natural spatial and temporal patterns of salinity, linking freshwater discharges to seasonal rainfall patterns and natural wetland hydrologic functions. Releasing fresh water to the estuaries in a manner that more closely approaches natural volumes and timing in relation to rainfall is expected to restore salinity regimes that are more supportive of native estuarine flora and fauna.

## How will the interim goal for this indicator be predicted?

Prediction methods differ by estuary and within different regions of the same estuary. For Florida Bay and Biscayne Bay, prediction methods have been formulated and are being considered for acceptance by the RECOVER Regional Evaluation Team.

**Florida Bay**

Several analysts, beginning with Tabb (1967), noted that salinities in Florida Bay's coastal embayments, as monitored at Everglades National Park fixed stations, were related to water levels in the Everglades. The relationship exists because "head", the rate of change between upstream and downstream water level, drives flow (e.g., Darcy's Law for groundwater flow and the Manning equation for surface water flow). Several series of regression equations have been developed to predict salinity in Florida Bay's coastal embayments based on stage at one or more upstream water level monitoring gauge. The Regional Evaluation Team selected a new series of multiple regression equations by Frank Marshall. These equations were developed based on observed daily average salinity at the Everglades National Park station in each embayment and observed average daily stage at selected Everglades National Park or South Florida Water Management District monitoring wells. The most appropriate monitoring wells and data lags to use were obtained through a combination of SARIMA analyses and MLR statistical tests (Marshall 2003). They each contain a distinct set of independent variables for salinity. Some of the equations include independent variables based on wind and sea level as well as stage data.

By basing the calculation of salinity in each embayment on a different set of independent variables (especially gauges), the Regional Evaluation team hoped to capture the separate effects on each embayment of the change in apportioning flow volumes among the southeast Everglades (C-111), Taylor Slough and Shark Slough drainages that are expected with CERP implementation.

**Manatee Bay/Barnes Sound**

Relationships between hydrology (i.e., stage) in upland reaches and coastal/nearshore estuarine conditions have been described for a number of South Florida coastal areas (i.e., Taylor Slough and northern Florida

Bay, Nuttle 2002; Florida Bay, Marshall 2003; and Barnes in southern Biscayne Bay, Alleman 2003, Aguirre 2003, Browder unpub.). Browder (unpub.) described a 'lag phased' relationship between stage at a well (SWEVER1) within the Card Sound/US 1 wetlands (the Triangle Area) and daily average bottom salinities at the mouth of Manatee Bay (monitoring station TG01) and Barnes/Card Sound (monitoring station TG02).

According to an analysis by Alleman (2003), marsh stage within the Triangle Area at gauge SWEVER1 (as predicted by the South Florida Water Management Model [SFWMM]) should average 1.9 feet, and vary between 1.25 feet and 3.2 feet in order to meet the above salinity targets. Additionally, the stage duration curve of model output should approximate the shape of a stage duration curve of a nonimpacted natural coastal wetland region while conforming to these average, minimum and maximum stages. The stated average, minimum and maximum stages and their related flows are expected to result in an average nearshore salinity of 20 parts per thousand (ppt) and a range between 0 and 30 ppt. If stage is highly correlated with rainfall, the appropriate timing of flow to the bay to meet the target criteria can be determined. Alleman's (2003) conclusion was consistent with results of a mass balance model by Aguirre (2003). The SFWMM provides information for estimating stage at the SWEVER1 gauge (and stage duration curve). Alleman's equation can be used to predict salinity in Barnes Sound as a function of stage at SWEVER1.

Surface salinity at one of these monitoring stations was analyzed to determine the relationship between salinity concentration and water level elevation in the upstream marshes (SWEVER1). Surface salinity at this staion was typically between 25 and 27 ppt. Water stage elevation at station SWEVER1 was typically between 1.44 and 1.46 feet. A linear relationship of average antecedent 30-day freshwater stage height and surface salinity nearshore in Barnes Sound for the period 1996-2001 was developed.

### South Biscayne Bay Coastal (Shoal Point to Turkey Point)

The flow output of the SFWMM will be compared against wet season and dry season requirements that were calculated by Meeder and confirmed by Alleman (2003). These are as follows:

- Wet season: 322,000 acre feet (average of 1,051 cubic feet per second for 7 months)
- Dry season: 146,000 acre feet (average of 347 cubic feet per second for 5 months)

Improvement will be evaluated as the percent of days when flows are at or above the required volume. Because, flow varies among months and even from year to year within months, as well as by season due to rainfall variation, volumes will be determined by month and compared to the wet and dry season targets defined for that month. Wet season months are June through October and dry season months are November through May. Initially, evaluation of progress in relation to interim goals will be calculated from SFWMM output as the percent of wet seasons and percent of dry seasons (in the 36-yr simulated record) in which the required total seasonal flows are achieved. Flows pertain to total flows from the following structures: S-123, S-21, S-21A, S-20G, and S-20F.

### How will we track whether the goals established for this indicator have been achieved?

Salinity is monitored throughout Biscayne and Florida Bays, and the northern estuaries. New monitoring stations are being installed in Biscayne Bay to improve resolution of salinity monitoring there, especially in western nearshore waters. Salinity records will be evaluated in relation to interim goals and other performance measures (RECOVER in prep.) formulated by RECOVER and described in the CERP Monitoring and Assessment Plan (RECOVER 2004). In addition, salinity records will be evaluated in relation to the performance measures formulated as part of the Florida Bay-Florida Keys Feasibility Study.

### What additional work is needed to improve this interim goal?

Readily usable predictive models for the northern basins of Biscayne Bay (Snake Creek, North Bay, Central Bay) and Whitewater Bay are being developed as an activity of the Regional Evaluation Team's Southern Estuaries Team. Predictive models are also needed for the Lower Ten Thousand Islands and the parts of Florida Bay not yet covered by predictive models. In general, prediction methods would be improved with improved estimates of stage and flows near the coast. For Florida Bay and Barnes Sound, in addition to the statistical models, mass balance and hydrodynamic models are being developed to predict salinity as a function of Everglades' hydrologic conditions. Following an evaluation of the models' performance, they may be used to revise the interim goal. Salinity predictors based on canal discharges are being developed for the Biscayne Bay areas not yet covered by models.

### References

Aguirre, C. 2003. Water Basin Model for Barnes Sound. Presentation to Southern Estuarine Team, Regional Evaluation Team, Restoration Coordination and Verification, c/o United States Army Corps of Engineers, Jacksonville District, Jacksonville, Florida, and South Florida Water Management District, West Palm Beach, Florida.

Alleman, R. 2003. Historic Salinity Contours. Powerpoint presentation on May 21, 2003 to Regional Evaluation Team, Restoration Coordination and Verification, c/o United States Army Corps of Engineers, Jacksonville District, Jacksonville, Florida, and South Florida Water Management District, West Palm Beach, Florida.

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Marshall, III, F.E., D. Smith, and D. Nickerson. 2003. Salinity Simulation Models for North Florida Bay, Everglades National Park. In: Joint Conference on the Science and Restoration of the Greater Everglades and Florida Bay Ecosystem "From Kissimmee to the Keys", Palm Harbor, Florida, pp. 53-55.

Nuttle, W.K. 2002. Hydrology and Salinity Models Applied to Historical and Hydrologic Restoration Scenarios. Report prepared for Everglades National Park, Homestead, Florida.

Nuttle, W. 2003. A Synthesis of Research on Florida Bay. Compiled for the Florida Bay Program's Science Oversight Panel with support from the Florida Caribbean Science Center, United States Geological Survey, Gainesville, Florida. April 2003 available at http://www.aoml.noaa.gov/flbay/draft/wkn_contents.pdf .

Tabb, D.C. 1967. Prediction of Estuarine Salinities in Everglades National Park, Florida, by the use of groundwater records. Ph.D. Dissertation, University of Miami, Coral Gables, Florida.

# INDICATOR G1.5 – WATER LEVELS IN LAKE OKEECHOBEE

## What is the restoration goal?

The restoration goals for water levels in Lake Okeechobee are 1) eliminate the occurrence of extreme high water levels, prolonged moderate high water levels, extreme low water levels and prolonged moderate low water levels, these being ecologically harmful conditions, and 2) maximize the occurrence of spring recessions, an ecologically beneficial condition.

## Why is this indicator important?

Sustained lake levels and a reduction of spring recession conditions have resulted in the loss and degradation of predrainage floral and faunal communities in Lake Okeechobee. Extreme high or low lake levels of any duration or moderate high or low lake levels of prolonged duration can cause significant harm to the ecosystem. When stage exceeds 15 feet, the lake's littoral zone, already much reduced from its historic extent, is flooded. When stage falls below 11 feet, the entire littoral zone is dry, and habitat is not available for wetland biota. The attributes of this indicator are identified in the Lake Okeechobee Conceptual Ecological Model (RECOVER 2004) as being directly linked to the recovery of plant and animal communities in the lake. Details are provided in Havens (2002). A number of CERP projects are expected to influence lake stage as a result of increased water storage facilities implemented under the CERP.

## How will the interim goal for this indicator be predicted?

The specific attributes associated with this indicator will be scored using the standard methods established during the C&SF Project Comprehensive Review Study, known as the Restudy, and currently in use during the Regional Evaluation Team process for evaluating alternatives. These methods are described in detail in the Lake Okeechobee Conceptual Ecological Model and Havens referenced above. The South Florida Water Management Model (SFWMM) will be run at each five-year increment, taking into consideration the CERP projects anticipated to be on line at those time steps. A 36-year hydrograph is provided for Lake Okeechobee at each time step, and these hydrographs are used to score expected lake stage. The metrics are 1) extreme high water level - lake stage in excess of 17 feet; 2) prolonged moderate high water level - stage in excess of 15 feet for more than 12 months; 3) extreme low water level - stage below 11 feet; 4) prolonged moderate low water level - stage below 12 feet for more than 12 months; and 5) spring recession - a desired gradual decline in stage from near 15.5 feet in January to near 12.5 feet in June. The CERP goal for the first four indicators is to have no such events. The goal for spring recession is to have events occurring every year.

Counts are made of the number of times that specified extremes are exceeded (or spring recession goals are met), and standardized to the number of events per decade. For each hydrologic indicator, the interim goals document will include a graph showing the standardized score at each five-year time increment. In other words, at each time increment, we consider the expected lake performance, taking into consideration the CERP components that are expected to be on-line at those times, and the range of possible climate conditions that might occur, as represented by the 36-years encompassed by the SFWMM.

Figure 6 is example output for this indicator (Water Stages in Lake Okeechobee, subindicator Extreme High Water Level). Interim goals are presented in terms of number of events expected to occur per decade, based on output from the SFWMM. For this indicator, the restoration target is 0, which is indicated here as being achieved in 2030. This is an example only, using hypothetical results.

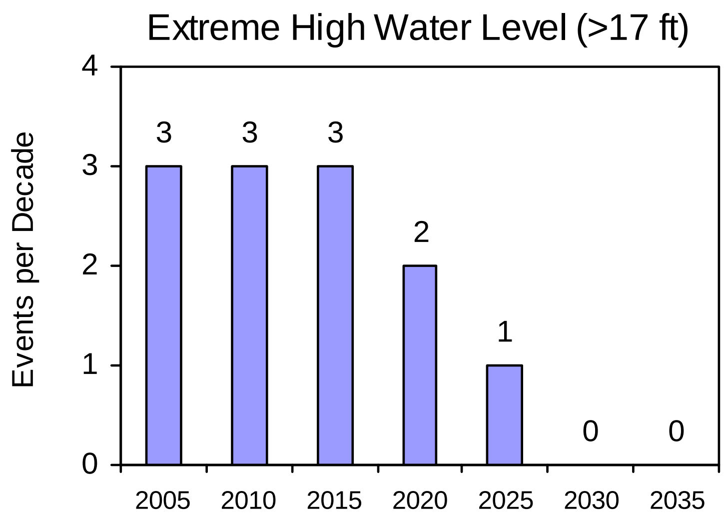


**Figure 6.** Example of output for the subindicator extreme high water level

### How will we track whether the goals established for this indicator have been achieved?

By determining the extent to which the harmful high and low water levels are reduced in their occurrence, and spring recessions are increased, we can assess the success of the CERP in regard to restoration of ecological values in the lake.

### What additional work is needed to improve this interim goal?

There is no additional work necessary at this time.

### References

Havens, K.E. 2002. Development and application of hydrologic restoration goals for a large subtropical lake. *Lake and Reservoir Management* 18, pp. 285-292.

RECOVER. 2004. Appendix A: Draft Conceptual Ecological Models. In: RECOVER. CERP Monitoring and Assessment Plan. Restoration Coordination and Verification, c/o United States Army Corps of Engineers, Jacksonville District, Jacksonville, Florida, and South Florida Water Management District, West Palm Beach, Florida.

# INDICATOR G1.6 – LAKE OKEECHOBEE PHOSPHORUS

## What is the restoration goal?

The restoration goal for Lake Okeechobee phosphorus is reduce long-term average concentration of total phosphorus in the lake's pelagic zone to 40 parts per billion (ppb).

## Why is this indicator important?

Elevated concentrations of phosphorus, due to excessive inputs from agricultural development in the watershed, have resulted in lake conditions that have created noxious algae blooms, expansion of cattail, loss of macroinvertebrate diversity, and other adverse ecological changes in the lake during the last 30 years, as documented in the Lake Okeechobee Conceptual Ecological Model (RECOVER 2004) and the peer reviewed literature.

A number of CERP projects are expected to influence water quality as described in the conceptual ecological model for the lake. Three of these projects are expected to directly and positively affect lake water quality.

## How will the interim goal for this indicator be predicted?

Total phosphorus concentrations in the pelagic zone of Lake Okeechobee will be modeled using the Lake Okeechobee Water Quality Model (LOWQM). This model was used to evaluate water quality responses during the C&SF Project Comprehensive Review Study, known as the Restudy, and it is the model being used for the lake in the Initial CERP Update. One key aspect of using the LOWQM for the interim goals is specification of boundary conditions, in particular the historic changes in nutrient inputs to the lake. This application will be consistent with how the model was applied in the recently completed Lake Okeechobee Sediment Removal Feasibility Study. In particular, certain assumptions will be made regarding the trajectory of phosphorus load reduction between now and 2015, and assumptions about how projects constructed to control phosphorus loads will influence loads of nitrogen to the ecosystem.

In regard to phosphorus inputs, assumptions are based on the fact that the load must be reduced to 105 metric tons per year (plus 35 metric tons per year from atmospheric deposition) by 2015. This is a legally-mandated loading reduction associated with the Lake Okeechobee Total Maximum Daily Load (TMDL) Rule. For restoration planning purposes in the Lake Okeechobee Protection Program, the Florida Department of Environmental Protection, Florida Department of Agriculture and Consumer Services, and South Florida Water Management District consider that agricultural best management practices will accomplish 25 percent of the necessary load reduction, and that the remaining 75 percent will occur due to the CERP and other watershed projects identified in the Lake Okeechobee Protection Plan, which was delivered to the Florida Legislature on January 1, 2004. Estimating only very general timelines for completion of the Lake Okeechobee Watershed Project features of the CERP and the Lake Okeechobee Protection Plan (see below), the following are the boundary conditions for the LOWQM:

- A linear decline in phosphorus loading to the lake to 75 percent of the current loading rate by 2010

- Between 2010 and 2015, a reduction of phosphorus loading to the TMDL target of 105 metric tons per year from surface inflows.

The LOWQM will be run for a period of time sufficient for the in-lake concentration of total phosphorus to stabilize at the TMDL goal of 40 ppb. This occurs after 2060. The long response time of the lake is due to the high rate of internal recycling of phosphorus from the lake sediments, which contain a large pool of phosphorus from past loading. The output of the LOWQM indicates a high degree of year-to-year variation in total phosphorus, due to the effects of wind and other forces on sediment recycling. To specify interim goals at five-year increments, a smooth curve (e.g., a first order polynomial or log function) will be fit to the model output, and approximate values extrapolated from that curve. The interim goals then will be presented in a table that will accompany the figure. It is important to note that this model assumes a constant rate of sediment deposition, whereas actual deposition rates might decline as loads are reduced. Should this occur, response time of the lake may be longer.

Figure 7 contains **example** output from the LOWQM, showing predicted response of in-lake total phosphorus to the loading reduction described in the text to meet the mandated TMDL of 105 metric tons per year (surface water inputs) by the year 2015. The lake reaches the goal of 40 ppb in approximately 2060. The jagged nature of the line reflects the important role of internal phosphorus recycling in controlling water column total phosphorus in this shallow wind-driven lake. The graph will be accompanied by a table that gives the 5-year rolling average values of the performance indicator.

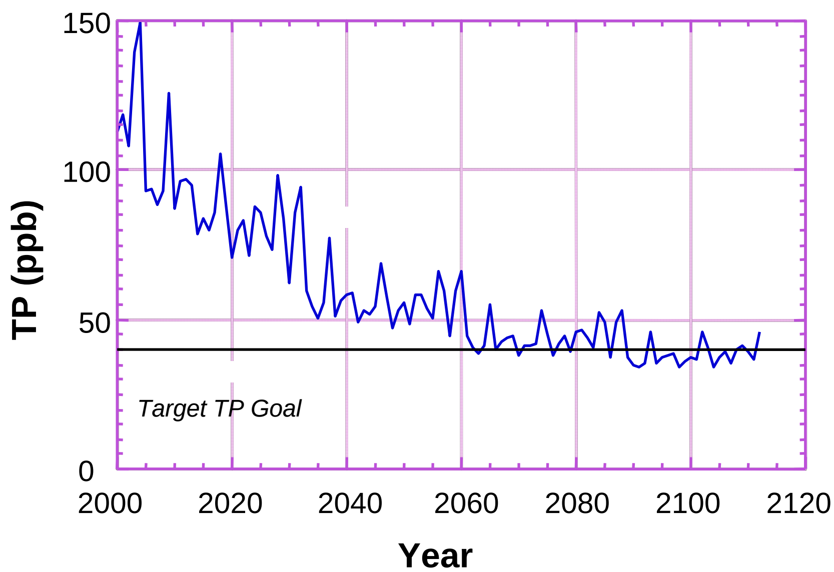


**Figure 7.** Example output from the LOWQM, showing predicted response of in-lake total phosphorus to the loading reduction

### How will we track whether the goals established for this indicator have been achieved?

The rate at which lake water total phosphorus concentration drops to 40 ppb will be used to assess the success of this interim goal on reaching its target.

### What additional work is needed to improve this interim goal?

The assumptions described above introduce uncertainty into the simulation, but at this time, there is not exact information regarding the timing and expected load reduction for the watershed projects to be constructed under the CERP or the Lake Okeechobee Protection Plan. As more specific information becomes available, as major projects get underway, it can be incorporated into future interim goal scenarios.

## References

Havens, K.E., N.G. Aumen, R.T. James, and V.H. Smith. 1996. Rapid ecological changes in a large subtropical lake undergoing cultural eutrophication. *Ambio* 25, pp. 150-155.

RECOVER. 2004. Appendix A: Draft Conceptual Ecological Models. In: RECOVER. CERP Monitoring and Assessment Plan. Restoration Coordination and Verification, c/o United States Army Corps of Engineers, Jacksonville District, Jacksonville, Florida, and South Florida Water Management District, West Palm Beach, Florida.

# INDICATOR G1.7 - LAKE OKEECHOBEE ALGAL BLOOMS

## What is the restoration goal?

The restoration goals for Lake Okeechobee algal blooms are 1) reduce the frequency of Lake Okeechobee chlorophyll *a* concentrations in excess of 40 ppb (“algal blooms”) to below 5 percent of samples, as a 5-year rolling average; 2) increase the pelagic total nitrogen:total phosphorus ratio to above 22:1 (by mass) as a 5-year rolling average; and 3) increase the ratio of pelagic diatoms:cyanobacteria to above 1.5, as a 5-year rolling average.

## Why is this indicator important?

Blooms of noxious blue-green algae have become common in Lake Okeechobee due to excessive phosphorus concentrations and the resulting low ratio of total and dissolved inorganic nitrogen:phosphorus. Blooms threaten fish, wildlife and drinking water quality in the lake, as documented in the Lake Okeechobee Conceptual Ecological Model (RECOVER 2004). The occurrence of nuisance blooms of cyanobacteria (blue-green algae) is one of the most visible signs of water quality impairment in the lake. The mandated reduction of phosphorus loading under the Total Maximum Daily Load (TMDL) Rule was developed in order to substantially reduce bloom occurrence in the lake’s shoreline regions.

A number of CERP projects are expected to influence water quality as described in the conceptual ecological model for the lake. Three of these projects are expected to directly and positively affect lake water quality.

## How will the interim goal for this indicator be predicted?

The Lake Okeechobee Water Quality Model (LOWQM) will be run as described for Indicator G1.6 (Lake Okeechobee Phosphorus), and plots generated, showing 1) percent of yearly chlorophyll *a* (CHLA) samples with concentrations in excess of 40 ppb (i.e., bloom frequency); 2) total nitrogen:total phosphorus mass ratio, which is directly related to the occurrence of bloom forming cyanobacteria in freshwater lakes, including Lake Okeechobee; and 3) the ratio of diatom:cyanobacteria biovolume. The latter is an indicator of the overall quality of the phytoplankton community, in that a higher ratio indicates a lower risk of blooms and also better food quality for zooplankton and the pelagic food web. As with the plot for total phosphorus, smooth curves will be fit to the model output, and conditions extrapolated from that curve at five-year intervals. The results will be presented in a summary table.

## How will we track whether the goals established for this indicator have been achieved?

In-lake monitoring is designed to provide data necessary to quantify the following parameters: pelagic total phosphorus; pelagic nitrogen:phosphorus ratio; diatom:cyanobacteria ratio; and algal bloom frequency.

## What additional work is needed to improve this interim goal?

The simulations for the Interim Goal exercise assume that reductions of nitrogen loads will be equivalent with reductions of phosphorus loads. This simple assumption is made because there are no data to support any more complex relationship. Therefore, this indicator, which is related to both phosphorus and nitrogen availability and its influence on algae in the lake, is uncertain. Additional research and model development is needed to better predict how the watershed, projects constructed in the watershed, and the lake itself processes phosphorus relative to nitrogen.

It also should be noted that this modeling approach described above will provide a conservative estimate of lake benefits from phosphorus load reduction, in that algal blooms in the pelagic region are largely controlled by high turbidity in the water, which in turn is driven by wind-resuspension of bottom sediments. The LOWQM does not consider algal bloom frequency in the lake's shoreline region, which is the area of greatest use by wildlife and society, and the area where blooms are most sensitive to changes in phosphorus concentration. When the Lake Okeechobee Environment Model (LOEM), a coupled hydrodynamic, sediment transport, water quality model, is completed in 2004, we will switch to using that model for evaluating interim goals related to algal bloom indicators, because unlike the LOWQM (which treats the lake as one mixed unit), the LOEM allows for prediction of trends in blooms in specific regions of the lake. The LOEM will be reviewed by the Model Refinement Team and the Regional Evaluation Team before incorporation into this process.

The output will be in the form of a graph, of the same format as shown in the example for Indicator G1.6. The graph will be accompanied by a table providing the 5-year rolling average values for each subindicator.

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# INDICATOR G2.1 – GREATER EVERGLADES WETLANDS TOTAL PHOSPHORUS

## What are the restoration goals?

The restoration goals for total phosphorus are 1) maintain/decrease 5-year geometric mean surface water total phosphorus concentrations in marshes in the Greater Everglades Wetlands to less than or equal to 10 micrograms per liter (µg/L), 2) reduce external loads entering the Everglades, 3) maintain/decrease marsh soil total phosphorus concentrations to less than or equal to 400 milligrams per kilogram (mg/kg), 4) maintain/restore the spatial distribution and abundance of biotic indicators (e.g., ridge and slough habitat, periphyton community composition) of natural oligotrophic conditions.

## Why is this indicator important?

Elevated phosphorus concentrations, primarily from agricultural runoff, have resulted in the loss of native periphyton communities, development of monotypic cattail stands, increased phosphorus storage in the soils, loss of open water habitat, change in dissolved oxygen status, and other adverse ecological changes over the last 30 years (DeBusk et al. 2001, McCormick et al. 2001).

CERP projects will have a variety of effects on the storage and dynamics of phosphorus in the Everglades. Some projects will directly improve surface water quality through new stormwater treatment areas (STAs). Enhanced water storage (such as reservoirs) will enable more timely distribution of water through STAs, increasing their effectiveness in cleaning the water of excess nutrients. Importantly, the longer hydroperiods that are targeted in multiple CERP components will reduce the extent to which overdrained soils oxidize and release stored phosphorus to the water column.

## How will the interim goal for this indicator be predicted?

Total phosphorus in the soil and water column of the greater Everglades will be modeled using the Everglades Landscape Model (ELM). Figure 8 is an **example** of an evaluation of net phosphorus accumulation during the duration of 31-year/36-year simulations. The example shows relative comparisons among five ELM model output runs using five different inflow phosphorus concentrations applied to a single set of hydrologic flows/assumptions (i.e., one run of the South Florida Water Management Model [SFWMM]). The actual graphic for this interim goal evaluation would compare five (or more) different interim goal simulations (e.g., 2010, 2015, etc.). The indicator regions (total of 58) denote ecological regions and gradients of interest and will be further refined.

In evaluating the multi-decadal performance under the assumptions of each 5-year initialization of the interim goal simulations, the total phosphorus accumulation in one simulation (e.g., 2010 assumptions) can be compared relative to any other initial-year's assumptions (such as the 2030 interim goal assumptions). An evaluation of water column phosphorus concentration can be used in a similar fashion. Both performance evaluations will also include output in the form of regional maps showing the difference among the model outputs.

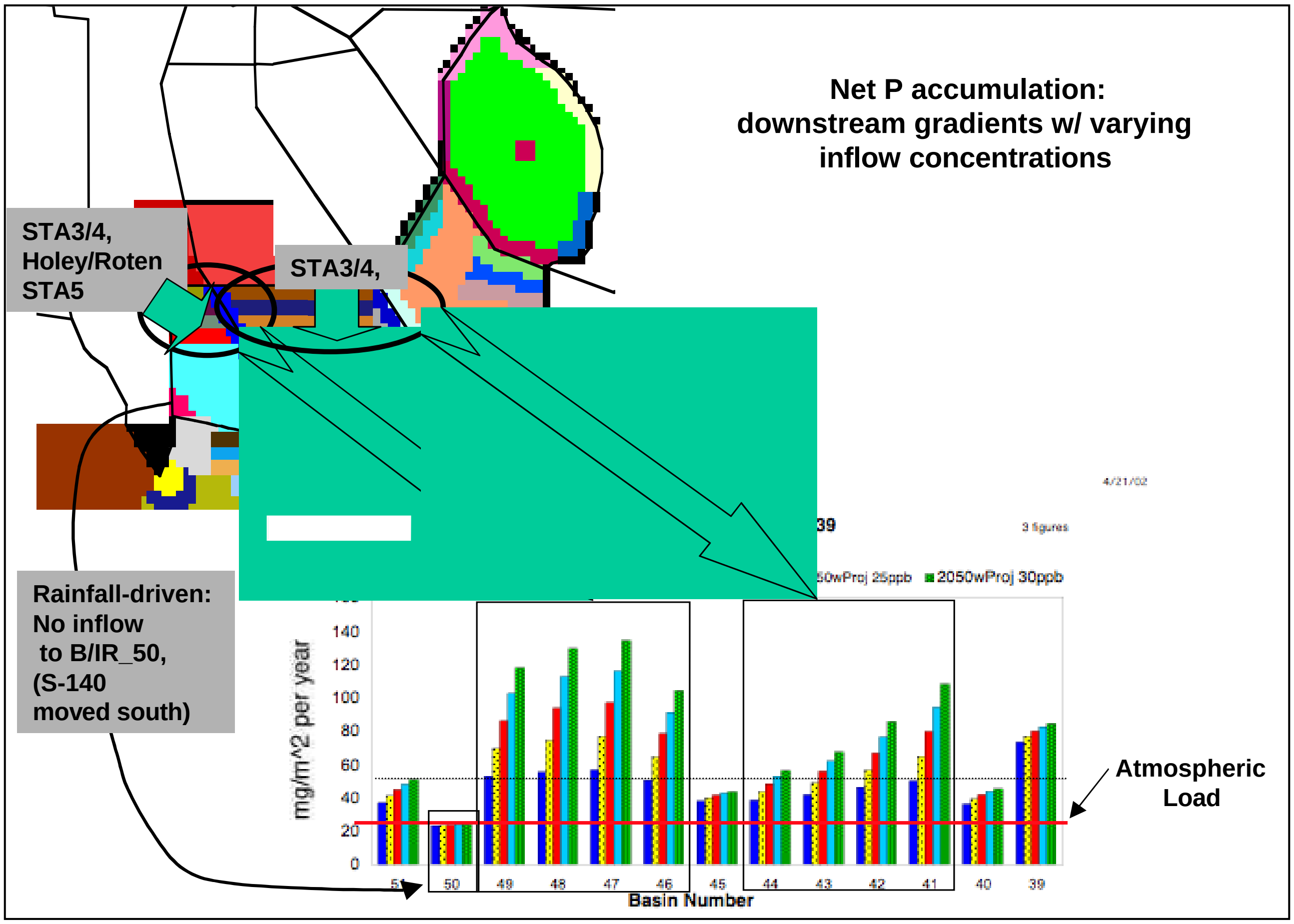


Figure 8. An example from northern Water Conservation Area of an assessment of net phosphorus (P) accumulation over the duration of 31-year/36-year simulations

**How will we track whether the goals established for this indicator have been achieved?**

Information collected from 5-year geometric mean surface water total phosphorus concentrations, separated into sites defined as impacted and unimpacted (according to Florida Department of Environmental Protection Rule 62-302.540 Water Quality for Phosphorus Standards within the Everglades Protection Area, as specified by the Everglades Forever Act Chapter 373, F.S. 403) will be coordinated with specific sites relative to the effects of CERP projects in establishing transects as defined in the *CERP Monitoring and Assessment Plan* (RECOVER 2004). Additionally, surface benthic material will be collected at 0-10 and 10-20 centimeter soil depths every two years along the same transect sites as those established for water quality. System-wide soil nutrient distribution will be measured throughout the entire greater Everglades every five years. The above metrics will be evaluated in close association with other responses, such as periphyton and vegetation interim goals, to ensure that biological responses are consistent with maintenance/restoration of oligotrophic conditions. The collected data will not only serve to assess progress towards restoration, but the data are directly used in refinement and validation of those (same) ELM output variables.

## What additional work is needed to improve this interim goal?

For future interim goal assessments, additional information is required in order to refine the accuracy of the predictions of phosphorus and other ecological dynamics. Several key areas of research relative to soils/floc, macrophytes, and periphyton need be pursued for enhancing this understanding. This includes monitoring/research on soil/floc accretion and mineralization rates, periphyton responses to changing water and nutrient levels, and macrophyte responses to altered hydroperiods and soil characteristics.

The ELM will be refined as improved data sets become available. The current version of the model has been demonstrated to effectively capture the long-term seasonal dynamics of surface water phosphorus concentration throughout the region, including soil and vegetation properties along nutrient gradients (Fitz et al. 2003). This calibration performance of the phosphorus dynamics in ELM version 2.1 encompasses a 17-year (1979-95) time period, using more than 50 sites distributed across the greater Everglades region. Updates to the model, including the 1979-2000 simulation period of version 3.0, will provide performance validation and are directly integrated with the data collection efforts.

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## INDICATOR G2.2 - PERIPHYTON MAT COVER, STRUCTURE AND COMPOSITION

### What is the restoration goal?

The restoration goal for periphyton mat cover, structure and composition is restore the periphyton communities that were characteristic of the historic hydroperiod and low nutrient conditions in the greater Everglades wetland communities.

### Why is this indicator important?

Historically, three types of periphyton communities occurred in the Everglades 1) benthic mats or "sweaters" associated with short hydroperiods, 2) metaphyton (floating mats) associated with long hydroperiods and 3) acid-loving epiphyton (growing on plants) associated with long hydroperiods. Periphyton represents an important food resource that supports the intermediate trophic level marsh fishes and macroinvertebrates upon which wading birds and other larger vertebrates feed. The restoration of hydrology associated with the CERP is expected to enhance the cover, structure and composition of periphyton, which are considered to be regional indicators of the functional base of the Everglades food web.

### How will the interim goal for this indicator be predicted?

Limited data are available to accurately predict compositional and biomass performance in periphyton responses to hydrologic alterations. Current assessment is limited to broad periphyton community types associated with hydroperiod; therefore, predictions will be based on a periphyton Habitat Suitability Index (HSI) where benthic mats dominate short hydroperiod marshes (inundated 0-6 months), metaphyton (floating mats) dominate long hydroperiod marshes (inundated 6-30 months), and epiphyton dominate long hydroperiod soft-water marshes (e.g., the Arthur R. Marshall Loxahatchee National Wildlife Refuge).

The Periphyton HSI (Gaiser et al. 2003) is a time-averaged, spatially-variable index that is a function of the average hydroperiod for the simulation period and is partitioned into three models that represent the structurally different Everglades periphyton communities (Benthic, Metaphytic and Epiphytic). The suitability functions for each index are shown in Figure 9.

HSI values range between 0 and 1, with 0 representing regions not suitable and 1 representing regions suitable for periphyton. Model output includes spatial maps of mean annual periphyton HSI values and summary tables; thereby allowing for comparisons among interim simulations, indicator regions and landscape types. For example, Figure 10 illustrates the HSI spatial distribution for the natural system determined using the Natural System Model (NSM).

### How will we track whether the goals established for this indicator have been achieved?

This interim goal will be assessed by measuring periphyton indicators such as biomass, tissue phosphorus, species composition and vegetation patterns in appropriate wetland communities.

### What additional work is needed to improve this interim goal?

In order to include species composition and biomass as a goal or target and to ensure that the restored community reflects low nutrient conditions, further information derived from monitoring and experimentation is required. Monitoring is currently being done at several sites within the central and southern Everglades and this data provides an excellent baseline dataset. Much more rigorous information will be gathered as the *CERP Monitoring and Assessment Plan* (RECOVER 2004) is implemented. Experiments are needed to validate the assumptions or refine the data used to establish the periphyton HSI. This includes a better understanding of how water depth and flood duration affects periphyton community structure and how water quality and hydrology influence food web dynamics. Specific species composition and biomass responses under different hydrologic and water quality regimes are current being developed and are expected to be available by 2008.

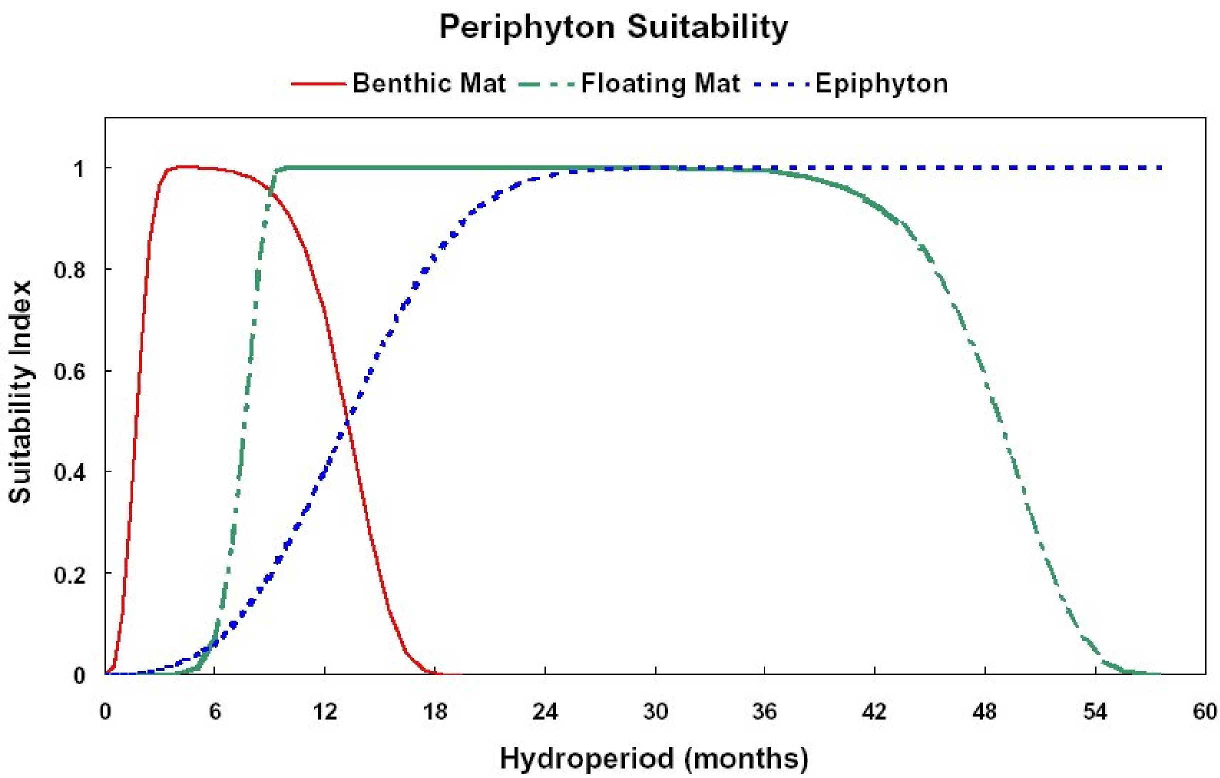


Figure 9. Habitat suitability functions for Everglades periphyton. Benthic mats dominate in short hydroperiod marshes (flooded 0-6 months), floating mats dominate in long hydroperiod marshes (flooded 6-30+ months), and epiphyton dominates in peat based long hydroperiod marshes (flooded 24-42 months).

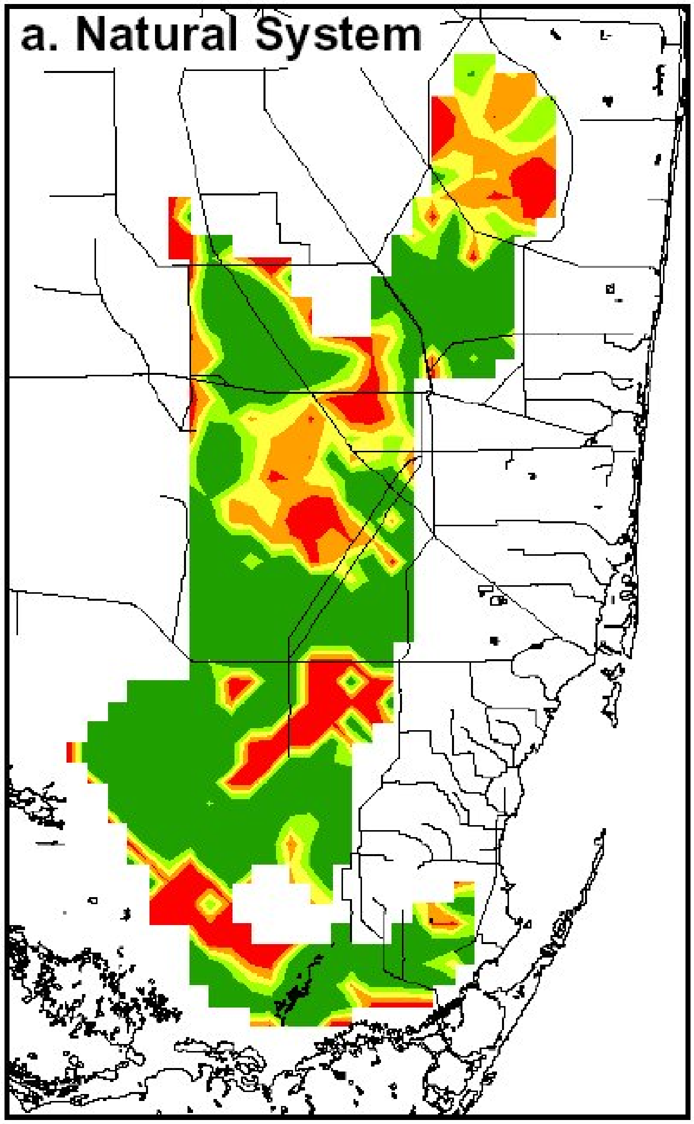


Figure 10. Distribution of suitable periphyton habitat determined for the natural system using the NSM. Colors indicate habitat suitability: red (0-0.2), orange (0.2-0.4), yellow (0.4-0.6), light green (0.6-0.8), and green (0.8-1.0).

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# INDICATOR G2.3 - RECOVERY OF THREATENED AND ENDANGERED SPECIES AND SUPPORTING HABITATS - SNAIL KITE

## What is the restoration goal?

The restoration goal for snail kites it to improve snail kite foraging habitat (vegetation structure) and promote primary prey (apple snail) recruitment throughout the South Florida ecosystem.

## Why is this indicator important?

Long-term snail kite population trends appear to correspond with the record of wetland drainage in South Florida (Bennetts et al. 1994). Snail kite habitats are affected by the primary stressors that the CERP will affect: hydrology and water quality. Therefore, the snail kite population is likely to be sensitive to the CERP and their monitoring has been proposed as a useful adaptive assessment, status report, and compliance monitoring function (CROGEE 2003). Improving habitat conditions for the snail kite, a Federally-listed endangered species, is important for the following reasons:

1) Snail kites are obligate wetlands species; i.e. they must live and feed within wetlands, which rely on a mosaic of native freshwater marsh habitats characteristic of much of the Everglades. Snail kites feed in the Everglades' marshes and along the shorelines of several lakes, in particular, Lake Okeechobee. A suitable distribution of *Eleocharis* and *Rhynchospora* dominated wet prairies and aquatic sloughs is necessary for snail kite foraging while areas with woody shrubs, such as tree islands, are optimal nesting locations (Kitchens et al. 2002) and characterize much of the habitat that the CERP strives to restore.

2) The species' primary current and historic distribution is within the area to be affected by the CERP. The distribution of snail kites is within five distinct watersheds throughout the state, but its two principal watersheds are the Kissimmee/Okeechobee/Everglades and Upper St. John's Basin. (Kitchens et al. 2002). Due to the spatial extent of marsh and shoreline habitats, the Everglades, particularly the Water Conservation Areas and Lake Okeechobee, encompass the majority of habitat for snail kites.

3) Recovery of threatened and endangered species is a task outlined by federal regulations and deemed worthy by the public. Recovery of listed species is a critical element of the South Florida Ecosystem Restoration Initiative as established by the South Florida Ecosystem Restoration Task Force. The U.S. Fish and Wildlife Service's South Florida Multi-Species Recovery Plan's (1999) recommendations for snail kite recovery and restoration of the ecological communities they inhabit are consistent with CERP restoration goals for major ecological features within the Everglades, thereby making snail kite habitat a suitable indicator of restoration success.

The snail kite has experienced population fluctuations associated with hydrologic influences, both man-induced and natural (Sykes 1983a, Beissinger and Takekawa 1983, Beissinger 1986), but the amount of fluctuation is debated. However, the abundance of its exclusive prey, apple snails (*Pomacea paludosa*), has been definitively linked to water regime (Kushlan 1975; Sykes 1979, 1983a) and the Everglades watershed has experienced, and continues to experience, substantial degradation including increased number and severity of untimely drydowns in many areas (Weaver et al. 1993). Drainage of Florida's interior wetlands has reduced the extent and quality of habitat for both the snail and the kite (Sykes 1983b). Apple snail populations, and therefore, snail kite habitat suitability, are particularly affected by severe and untimely drydowns (Darby et al. 1997).

Apple snails are more common in wet prairies that include emergent vegetation such as *Rhynchospora* spp. and *Eleocharis* sp. than in adjacent sloughs with sparse, floating and submerged vegetation such as *Utricularia* spp. and *Nymphaea* sp. (Darby 2003). Emergent vegetation allows the snails to easily access the water surface for respiration, where they are visible and accessible to foraging snail kites. On the other end of the extreme, in dry years, the snail kites depend on water bodies that normally are suboptimal for feeding, such as canals, impoundments, and small isolated wetlands, remote from regularly used sites (Beissinger and Takekawa 1983, Bennetts et al. 1988, Takekawa and Beissinger 1989). These secondary or refuge habitats, considered vital to the continued survival of this species in Florida, are being lost at a rapid pace. Therefore, an increase in area and heterogeneous distribution of natural foraging habitats through restoration may be essential to the long-term survival persistence of the species when faced with natural, yet severe habitat disturbances, such as drought.

Snail kite research (Bennetts and Kitchens 1997) also suggests that maintaining deep, impounded pools, like those seen in southern and eastern Water Conservation Area 3A under current conditions, will result in degradation of snail kite nesting habitat due to the loss of woody vegetation and degradation of foraging habitat due to the loss of wet prairie communities. Continuous flooding of wetlands for more than four of five years is particularly associated with degradation of snail kite foraging habitat (DOI 2001, Bennetts et al. 1998). In Water Conservation Area 3A, snail kites have increasingly moved their nesting activity to areas of higher elevations and shorter hydroperiods as lower elevation habitat areas have been degraded by high water levels sustained by water management practices (Bennetts et al. 1998). As this shift continues, snail kites may increasingly "run out" of suitable nesting habitats within Water Conservation Area 3A and be forced to move to other areas of suitable habitat (Kitchens et al., 2002).

In their analysis of how 15 vegetation studies relate to snail kite nesting and foraging habitat, Kitchens et al. (2002) concluded that all studies documented detrimental habitat alterations as a result of excessive depths and hydroperiods. C&SF Project operations have disrupted natural hydrologic patterns, reducing hydroperiods in some areas, and increasing them in others (Weaver et al. 1993). These hydrologic changes are identified as a stressor on the snail kite as an attribute of the CERP Total System Conceptual Ecological Model (Ogden and Barnes in prep.). CERP implementation should help to reverse these trends and support increasing areas of snail kite foraging habitat. In addition, excessive nutrient inputs promote dense growth of exotic and invasive native plants, particularly, cattail, water lettuce (*Pistia stratiotes*), water hyacinth (*Eichhornia crassipes*), and hydrilla (*Hydrilla verticillata*). Dense growth of these plants can reduce the ability of snail kites to locate apple snails. Expected water quality improvements, as a result of the CERP, should help promote the maintenance of a more natural, nutrient-poor system.

### How will the interim goal for this indicator be predicted?

Apple snail reproductive habitat and snail kite foraging habitat will be predicted using hydrologic output from the South Florida Water Management Model (SFWMM).

**Apple Snail Reproductive Habitat.** Because snail kites feed almost exclusively on apple snails, their survival depends directly on the hydrologic functioning of wetlands (Bennetts et al. 1998). Apple snails require water levels above ground surface in order to produce egg clusters, and newly hatched snails are less able to survive dry periods that are adult-sized snails (Darby 1997, 2003). Darby (1997, 2003) documented a peak in apple snail egg cluster production in March - April and suggested that dry outs below ground level prior to or during this peak can substantially reduce apple snail populations through reduced egg cluster production and reduced hatchling survival. Therefore, the apple snail reproductive habitat indicator will use output from the SFWMM to evaluate the number of years in which water levels fall below ground surface prior to May 1. Predicted water levels for April 30 of each year of the 36-year record will be averaged across each indicator region and compared to the average ground surface for each indicator region. The number of drydowns will be quantified for five-year increments throughout the

CERP project implementation. For the Lake Okeechobee littoral zone, the number of years in which predicted lake levels fall below 11 feet (approximately 95 percent of the littoral zone dry) will be counted. Fewer drydowns before May 1 than predicted by Natural System Model are desirable. The indicator will be applied to the Lake Okeechobee littoral zone and the following indicator regions established by the RECOVER Regional Evaluation Team: 100-102, 110-133, 140-146, 160, and 170 (RECOVER in prep.) (Figure 11).

**Snail Kite Foraging Habitat.** Based on Bennetts et al. (1998) and Bennetts (personal communication 2003), optimal snail kite foraging habitat supporting emergent wet prairie vegetation is maintained in areas where water levels fall below ground surface between 1 in 3 and 1 in 5 years (156-260 weeks average flood duration). Marginal habitat is maintained in slightly drier and slightly wetter areas with 1-in-2 to 1-in-3 year drydowns (104-156 weeks average flood duration) and 1-in-5 to 1-in-6 drydowns (260-312 weeks average flood duration). These hydroperiod classes correspond with the hydrologic requirements of emergent marsh vegetation reported in the scientific literature as reviewed in two recent publications (Wetzel 2001, SFWMD 1995).

Output from the SFWMM will be used to predict the average duration of flooding events (weeks per year) over the 36-year period of record. Indicator regions with average flood durations from 156 to 260 weeks will be considered optimal, indicators regions with average flood durations from 104 to 155 week or 261 to 312 weeks will be considered marginal. This indicator will be applied to the following indicator regions established by the RECOVER Regional Evaluation Team: 100-102, 110-133, 140-146, 160 and 170 (Figure 11) (RECOVER in prep). For snail kite foraging habitat in the Lake Okeechobee littoral zone, the existing Lake Okeechobee littoral zone indicators will provide an appropriate evaluation of habitat.

### How will we track whether the goals established for this indicator have been achieved?

The *CERP Monitoring and Assessment Plan* (MAP) (RECOVER 2004) does not currently include any snail kite, apple snail or snail kite habitat monitoring packages. However, several of the MAP's vegetation assessment monitoring components are likely to provide data that will allow for an assessment of snail kite habitat. Apple snail sampling and snail kite surveys are also not currently included in the MAP. The process of proposing apple snail monitoring and snail kite surveys for inclusion in the next version of the MAP will be initiated.

### What additional work is needed to improve this interim goal?

Additional work, in the field of model refinement and development may allow prediction of population size, growth rates and spatial distribution of the snail kite population. With the development and refinement of ecological models, we anticipate future interim goal prediction methodology that will vary from the current proposal. For example, the Across Trophic Level System Simulation (ATLSS) Model includes a snail kite spatially explicit suitability index (SESI) that will be useful for predicting the distribution of snail kite habitat. The Everkite model, developed by Wolf Mooij, Netherlands Institute of Ecology, is a spatially-explicit individual-based snail kite model that also has potential for future goal predictions (Mooij et al. 2002). However, the current version of the model is not recommended for predicting actual population numbers. Efforts should be made to improve the predictive ability of the Everkite and ATLSS SESI models; thus, making the models useful for setting interim goals.

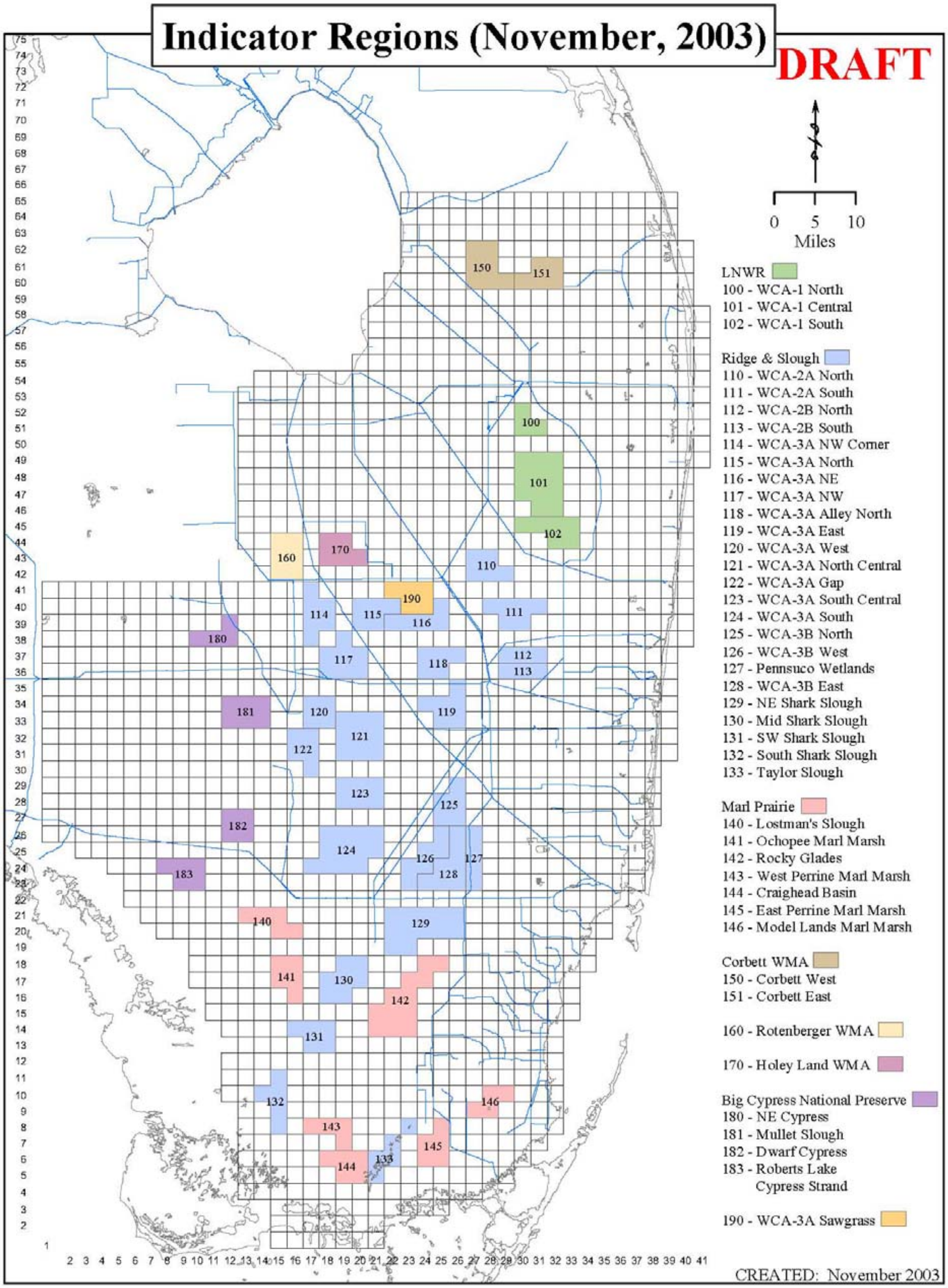


**Figure 11.** Indicator regions established by the RECOVER Regional Evaluation Team

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# INDICATOR G2.4 - RIDGE AND SLOUGH PATTERN

## What is the restoration goal?

The restoration goal for ridge and slough pattern is to improve conditions that restore the ridge and slough landscape directionality and pattern, support natural soil forming processes, and preserve microtopography.

## Why is this indicator important?

Predrainage ridge and slough landscape is characterized as expansive, long hydroperiod freshwater marsh with low velocity sheet flow, moderately deep organic soils, and alternating sawgrass ridge/open water slough communities (Davis et al. 1994, Gunderson 1994). These freshwater wetlands were important centers of primary production (periphyton, graminoids, water lilies), secondary production (crayfish, grass shrimp), and supported wading birds, turtles, freshwater fish, and alligators. The spatial extent of this landscape has been reduced dramatically by urban and agricultural expansion and water management practices (Davis and Ogden 1994), resulting in landscape compartmentalization, reduced sheet flow, loss of organic soils, altered flow patterns, water depths, water and soil chemistry, and introduction of exotic species (RECOVER 2004).

Field and remotely sensed observations show that all of the remaining ridge and slough landscape has been altered significantly from predrainage conditions, either in diminished vertical cross-section or in degraded horizontal pattern, or both. The original soil, topographic and vegetative pattern was the direct result of water depth differences, with microtopographic variations in the peat surface maintained by processes associated with long, landscape-wide, and uninterrupted flow paths. Significant areas have already been converted to nearly monospecific stands of continuous sawgrass that support a substantially reduced fauna. These observed changes suggest that current water management practices are not able to sustain the ridge and slough landscape in its original, diverse form (Science Coordination Team 2003).

CERP goals include improvements in soil forming processes, habitat, and plant and animal abundance and diversity. The heterogeneity of the ridge and slough landscape supports this diversity. The changes in the flow regime and water depths, associated with the CERP, will help restore the soil forming processes and consequently the microtopography characteristic of the ridge and slough landscape.

## How will the interim goal for this indicator be predicted?

There are four key hydrologic variables in the ridge and slough landscape area: water depths, annual variations in water depths, flow directions, and flow velocities. These four hydrologic variables have been integrated into a ridge and slough HSI.

The South Florida Water Management Model (SFWMM) will be used to calculate the ridge and slough HSI values for all model cells located within the remaining ridge and slough landscape. Index values are based on long-term average (e.g., 36-year period of record) hydrology modeled for the scenario, and are the geometric mean of the four subindices characterizing key aspects of water depth and flow. Although the ridge and slough landscape encompassed all three Water Conservation Areas, particular CERP emphasis may be placed on the region comprised of Water Conservation Areas 3A and 3B, Northeast Shark Slough, and Shark River Slough. The other portion of remaining ridge and slough landscape, Water Conservation Area 1 (Arthur R. Marshall Loxahatchee National Wildlife Refuge) and Water Conservation Area 2, originally formed part of a separate flowway and may exhibit a different level of response to the CERP.

Details of the HSI are available at the following web site:

http://www.sfwmd.gov/org/pld/hsm/reg_app/his/ridge_and_slough/index.html

The HSI will be presented by a color-coded map that shows likely suitability of future hydrologic conditions for preservation of the ridge and slough landscape.

**How will we track whether the goals established for this indicator have been achieved?**

In addition to plant community monitoring and soil and topography monitoring (in transects), the ridge and slough pattern will also be observed using aerial photographs (RECOVER 2004). A relatively new method for analysis of aerial photographs is available. Slough shape is characterized by the length and width of the slough. The landscape as a whole can be characterized by the spacing of the sloughs and the percent that is open slough compared to the percent that is covered by emergent sawgrass.

The proposed assessment method combines an analysis of lacunarity (related to the shape of the ridges and sloughs), percent area, mean distance/gap between ridges, and straight slough flow length. This analysis produces a pattern complexity value for regions of the ridge and slough habitat.

The Ridge and Slough Pattern Analysis Tool (RASPAT) has established a set of criterions and thresholds of “natural”, “deteriorating”, and “deteriorated” patterns of ridge slough landscape in the Everglades based on analysis of historic aerial photographs. The RASPAT will first be used to estimate the current spatial complexity of ridge and slough in Water Conservation Area 3 and Everglades National Park. It will then be used every 5 years to measure actual spatial complexity in these areas (based upon new aerial photographs).

**What additional work is needed to improve this interim goal?**

Ideally, a predicted interim goal would also be observable in the field. At this time the suitability index, while not observable in the field, is the best tool for predicting the condition of the ridge and slough habitat.

With improved understanding of the relationship between flow velocities and sediment movement and the indirect effects of canals, the RASPAT method may be developed into a predictive tool called the Ridge and Slough Pattern Simulation Model (RiSPSiM). If this tool is considered preferable to the existing suitability index the interim goal would be revised.

Another important area of work is in understanding the processes that maintain the characteristic microtopography. This would include studies of biomass production and soil accretion as well as organic matter decomposition and other factors. Understanding the complicated interaction between these processes may eventually result in a dynamic model that can precisely predict topographic changes.

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# INDICATOR G2.5 – EVERGLADES TREE ISLANDS

## What is the restoration goal?

The restoration goals for Everglades tree islands are 1) improve the health of tree islands in all Everglades Protection Areas considered to be stressed or degraded and maintain the status of healthy islands and 2) prevent reduction in tree island area.

## Why is this indicator important?

Tree islands are a small, but important, component of the mosaic of habitat types found in the Everglades ridge and slough. They harbor high plant species diversity and provide essential upland habitat for a variety of wildlife. Tree islands occur throughout the Everglades marshes. However, large regions that were once “peppered” with islands are now completely devoid of them (e.g., Water Conservation Area 2A), while some areas have seen a reduction of 60 percent (e.g., Water Conservation Area 3). Historically, tree islands have supported diverse vegetative communities that provide essential foraging and sheltering habitat for wildlife, especially during periods of high water, and provide nesting sites for wading birds and herpetofauna (e.g., freshwater turtles). Tree islands are also archaeologically important and have significant cultural importance to both the Miccosukee Tribe of Indians and the Seminole Tribe of Florida.

Several studies have shown that tree island vegetation is dependent upon hydrology (Heisler et al. 2002, Wu et al. 2002). Improvements in hydrology associated with the CERP are likely to protect vegetation communities on intact tree islands and to restore those on degraded islands.

## How will the interim goal for this indicator be predicted?

**Tree Island Species Richness.** It is assumed that hydropatterns predicted by the Natural System Model (NSM) include frequencies and durations of extreme depth conditions that would sustain appropriate species richness on elevated tree islands. The goal for this indicator is the deviation in predicted woody species richness from NSM at 5-year increments and at full plan performance.

Analysis of data collected in Water Conservation Area 3 suggest that woody species richness on elevated tree islands is an indicator of negative impacts from both island flooding and prolonged low water conditions (Heisler et al. 2002). Therefore, species richness is used as a surrogate measure for hydrologic impacts to tree islands (Heisler 2001). In general, this index is founded on a statistical expression of the relationship between field data of tree island vegetation condition and hydrologic variables predicted by regional models. The specific metrics for the index are expected to change over time with improved knowledge of hydrologic linkages to tree island vegetation condition.

The woody species richness will be predicted using hydrologic output from the NSM and the South Florida Water Management Model (SFWMM) for each of the 5-year increments modeled in the CERP update. The current chosen measure of tree island vegetation condition is the number of tree and shrub species observed on elevated islands in Water Conservation Area 3A. The current chosen hydrologic predictor variables are 1) the percent of weeks during the simulation that depths less than -1.0 feet, and 2) the percent of weeks during the simulation that depths greater than 2.0 feet, relative to SFWMM grid cell ground elevation (SFWMM version 3.5 validation and calibration simulation for rainfall years 1979-1995). This index is described in detail in Heisler et al. (2003). Using these high and low depths from SFWMM output, a predicted species richness score is calculated for each model grid cell.

A standardized measure of the deviation of the predictive hydrologic model from the NSM target is calculated and converted to the Species Richness Suitability Index.

The model results will be displayed using maps of tree island species richness plotted over the applicable regions of the Everglades and summarized in a time-series table by basin.

**Tree Island Extent.** This part of the interim goal quantifies the number and aerial extent of tree islands in Water Conservation Areas 2 and 3 as a function of competition with surrounding habitats in relation to drought, fire, hydroperiod and water depth. This goal will be based upon the Everglades Landscape Vegetation Model (ELVM). ELVM currently predicts the competitive interaction between a generic tree island and the surrounding ridge and slough as a function of past and present habitat condition.

The ELVM predicts landscape-scale changes in the aerial extent of tree islands (Wu et al. 2002). The ELVM simulates the establishment, growth and competition of individual community types at a grid cell resolution of 100 x 100 meters. This high spatial resolution gives ELVM more control over seed distribution, rhizome extension, exotic species invasion and succession. Vegetation growth and competition in the model were controlled by subsets of environmental factors that include hydroperiod, nutrients, salinity, elevation, precipitation, fire, hurricanes and freezes. In ELVM, five vegetation community types (cattail, sawgrass, wet prairies, sloughs and tree islands) compete with one another for nutrients, water and space. The life cycle of each community type within a cell is simulated including establishment, growth, expansion, mortality and succession. Life cycles of each community type are simulated based on growth strategies (e.g., seed germination versus vegetative expansion). These competition and colonization growth strategies can cause a shift in dominance to another community within the cell. The details and mechanism of each function (e.g., succession, growth, mortality, disturbance, hydrology and elevation) in the ELVM are described in Wu et al (2002).

The model results will be displayed using maps of tree island size and location plotted over the applicable regions of the Everglades and summarized in a time-series table by basin.

### How will we track whether the goals established for this indicator have been achieved?

The tree island interim goal will be assessed by analysis of aerial photos every five years and measuring tree island native canopy density and diversity, understory composition and structure, exotic plant density, and tree growth as described in the *CERP Monitoring and Assessment Plan* (RECOVER 2004).

### What additional work is needed to improve this interim goal?

**Tree Islands Species Richness.** Additional information is needed to cross-validate the SRSI index for possible application outside of Water Conservation Area 3. This information would include evaluation of correlations between species richness and existing data on tree island species richness for islands outside Water Conservation Area 3, followed by modification of the index's depth criteria and/or weighting coefficients as needed.

Because the temporal lag in the response of species richness to hydrology is unknown, this index is not intended to predict actual species richness changes over time, but rather the suitability of hydrology for tree island vegetation. However, collection of data needed to evaluate the tree island extent indicator along with field hydrologic data should permit the eventual development of a single index for combining the prediction and evaluation of tree island vegetation change over time.

**Tree Island Extent.** Field data that is needed to improve ELVM and make it applicable to Water Conservation Area 1 and Everglades National Park includes 1) distribution of tree island elevations, 2) distribution of tree island types, and 3) distribution of peat depths on tree islands.

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# INDICATOR G2.6 - SPATIAL EXTENT OF CATTAIL HABITAT

## What is the restoration goal?

The restoration goal for the spatial extent of habitat is to reduce expansion and minimize area of cattail in the Everglades Protection Area.

## Why is this indicator important?

Changes in hydrology and phosphorus inflows over the last 30 years have resulted in a conversion of ridge and slough vegetation to cattail (Newman et al. 1996). Large areas of Water Conservation Areas 2A and 3A have been invaded by cattail (Rutchey and Vilchek, 1998). This conversion to cattail tends to fill in the deep water sloughs needed as refuge by aquatic organisms during the dry season. Conversion to cattail can also change the biodiversity, soil structure and the basic biogeochemical processes needed to sustain the oligotrophic nutrient regimes and the organic structure of both ridges and sloughs (Sklar et al. 2001, 2002, 2003).

As the CERP improves the hydrologic conditions in the Everglades, the vegetative communities will adapt to the new conditions. The changes in habitat are important indicators of ecosystem restoration because they support specific animals. In particular, the dense stands of cattail found in the system today are expected to be reduced by the CERP through improvements in water quality and in hydrology.

## How will the interim goal for this indicator be predicted?

Prediction of this indicator will be based upon the ELM, used on a basin-by-basin delineation throughout the greater Everglades system (Fitz and Sklar 1999). The ELM is a carbon balance model that calculates plant production, reproduction and decomposition as a function of current soil characteristics, habitat type, climate, hydrology and nutrient inputs. It predicts habitat type and habitat change as a function of biogeochemical feedbacks and cumulative impacts that over time alter the environment. Indicator regions can be selected to encompass subregions of potential change, principal habitats, and principal gradients downstream of point source inflows into and within system.

The output of the model will be presented as a histogram of presence/absence of macrophyte community types for each basin and as maps of cattail community distributions.

## How will we track whether the goals established for this indicator have been achieved?

The spatial extent of cattail in the Everglades can be assessed by analyzing aerial photographs to determine vegetative cover.

## What additional work is needed to improve this interim goal?

In general, the predictive models would be improved by a better understanding of what is required, biogeochemically, to revert back to natural sawgrass and slough communities once a region has become dominated by cattail. Additionally, the ELM is currently undergoing a peer review process. Once that review is completed, the model may require modifications before it is more widely accepted, and interim goals that depend upon its predictive capabilities may be reclassified in Group 1.

Interim goals for the spatial extent of other landscape features should eventually be developed. At this time, acceptable methods for the prediction of the spatial extent of uplands, marl prairies and mangroves are not available. It is known that these habitat types support important elements of the Everglades ecosystem. It is also expected that the CERP will affect spatial extents as hydroperiod changes in the marl prairies (and adjacent to the uplands) and freshwater discharge through the mangrove zone changes.

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# INDICATOR G2.7 - SUBMERGED AQUATIC VEGETATION IN SOUTHERN ESTUARIES

## What is the restoration goal?

The restoration goal for submerged aquatic vegetation (SAV) in southern estuaries is to establish and sustain diverse Florida Bay seagrass communities, with moderate plant densities and more natural seasonality, covering 65-70 percent of suitable bay habitat.

## Why is this indicator important?

Seagrass beds are a key component of South Florida estuarine ecosystems, providing critical food and habitat for shrimp, fish and other organisms. Seagrass beds also stabilize sediments, thus promoting clear water and helping to minimize algal blooms. Seagrass species composition, abundance and spatial distribution are affected by spatial and temporal salinity patterns and nutrient and light levels. Freshwater inflow patterns (quantity, timing and spatial distribution) affect salinity, nutrients and light.

Restoring more natural freshwater inflow patterns and water quality improvements, as proposed by the CERP, are expected to result in more diverse estuarine seagrass communities, with moderate plant densities and more natural seasonality, and increase spatial coverage of suitable habitat. The spatial distribution and extent (coverage) of seagrass community types represents an effective indicator of estuarine SAV response to proposed CERP projects. This indicator is also used in other estuarine ecosystem management programs (e.g., Chesapeake Bay, and Indian River Lagoon, Charlotte Harbor, and Tampa Bay National Estuary Programs) to assess SAV response to water quality, including salinity and restoration activities.

Seagrass is an important ecological attribute, and a focus of CERP actions, in most South Florida estuaries. However, based on the indicator selection criteria of predictability (including adequate existing data and monitoring), ecosystem restoration effect (and thus importance), ease of recognition and understanding by the intended audience, and to have a manageable total number of indicators, the proposed SAV indicator for the southern estuaries region will focus only on Florida Bay. The best developed seagrass models for predicting the defined metrics are for Florida Bay and progress on developing coastal hydrologic/hydrodynamic models to predict salinity patterns, on which the seagrass models depend, is greater for Florida Bay than other estuaries. Florida Bay also has the best existing data and monitoring for the proposed indicator. CERP actions will likely affect a larger spatial extent of seagrass coverage and biomass in Florida Bay than in other South Florida estuaries. Finally, Florida Bay is better known and receives more attention by policymakers and the public (the intended audience) than other estuaries, especially since the recent seagrass mass mortality in Florida Bay.

**How will the interim goal for this indicator be predicted?**

Predictions of spatial distribution, spatial coverage and seasonality of Florida Bay seagrass community types will be based on statistical (Fourqurean et al. 2003) and mechanistic (Madden et al. 2003) models. Predictions will be presented in the form of maps, graphs and tables with supporting text. Figure 12 provide an example presentation of the Fourqurean et al. (2003) statistical SAV model predictions.

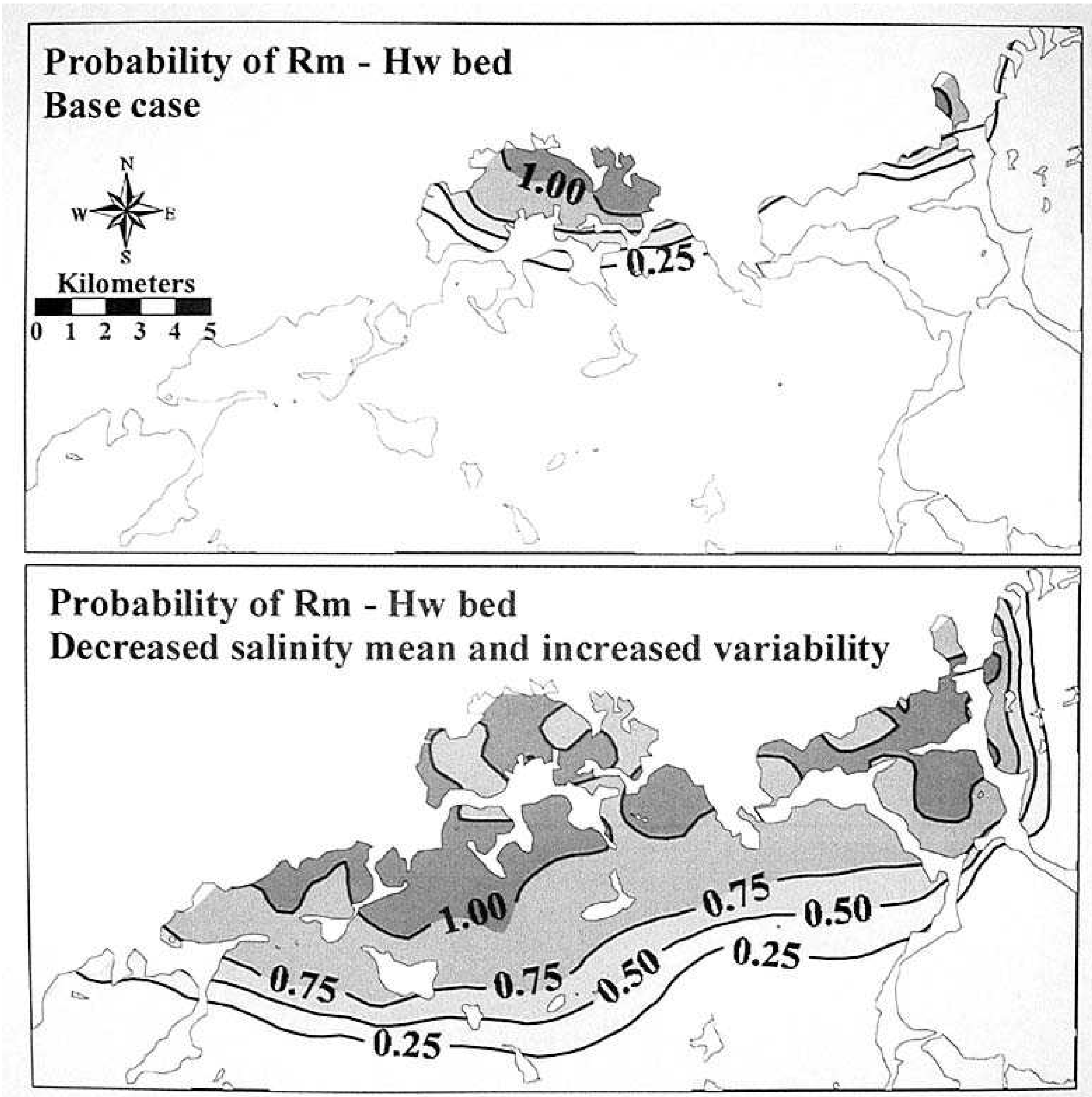


**Figure 12.** An example presentation of the Fourqurean et al. (2003) statistical SAV model predictions

### How will we track whether the goals established for this indicator have been achieved?

Modeling parameters (metrics) for predicting this indicator include following:

- Percent cover and relative abundance of seagrass (*Thalassia, Halodule, Ruppia*) and macroalgal species.

- Biomass and relative abundance of *Thalassia*, *Halodule* and *Ruppia*.

- Spatial distribution and extent (coverage) of seagrass community types (based on percent cover and biomass data). The community types are sparse *Thalassia* bed, dense *Thalassia* bed, *Halodule* bed, dense mixed species bed, *Ruppia*-*Halodule* community, and no seagrass (as defined in Fourqurean et al. 2003).

- Seasonal variation (end of dry and wet season) in these measures.

These parameters are also part of existing Florida Bay seagrass monitoring programs (Durako et al 2003) and the proposed *CERP Monitoring and Assessment Plan* (MAP) (RECOVER 2004), with the exception of seasonality. The MAP proposes only end of dry season sampling; however, end of wet season sampling should also be conducted.

Complementing this predictive indicator will be an indicator with similar measures that will track actual conditions and changes in Florida Bay seagrass over time. This indicator will assess actual progress toward achieving the CERP Florida Bay seagrass restoration goal. Status and trends data for this indicator will come from the CERP monitoring and assessment program.

Multi-annual rainfall patterns (e.g., drought), tropical storms and sea level rise could affect CERP estuarine ecosystem restoration actions and its ability to attain goals and targets, including those for Florida Bay seagrass. These factors, although external to the CERP, and consequently not controllable by the CERP, need to be considered in evaluating program performance.

### What additional work is needed to improve this interim goal?

The interim Florida Bay seagrass restoration goal is based on an estimate of ecosystem conditions prior to major human interventions. These conditions (i.e., Florida Bay ecosystem history) are determined from paleoecological research and historical accounts (see Brewster-Wingaard et al. 2003). Additional ecosystem history research will help refine this interim goal.

Additional work needed to improve the prediction of the indicator for this interim goal is as follows:

- The Madden et al. (2003) mechanistic seagrass model is still being developed. The model currently predicts *Thalassia* biomass, but not biomass for *Halodule* and *Ruppia*. The model should be able to predict biomass for all three species in early 2004. The model should be able to incorporate interspecific competition by mid-2004.

- The seagrass models depend on predictions of salinity patterns from coastal hydrologic/hydrodynamic models. The CERP program has not yet selected and implemented these coastal models. Some coastal models are still being developed and verified.

- A Florida Bay landscape seagrass model that will help apply the Madden et al. model predictions on a bay-wide scale needs to be completed.

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# INDICATOR G2.8 - JUVENILE SHRIMP DENSITIES IN FLORIDA AND BISCAYNE BAYS

## What is the restoration goal?

The restoration goal for juvenile shrimp densities in Florida and Biscayne Bay is increase juvenile pink shrimp density at peak abundance during the period August-October in optimal habitat (seagrass) in three regions of Florida Bay, in Ponce de Leon Bay on the lower southwest mangrove coast, and in western nearshore southern Biscayne Bay. Specific restoration goals include 17 shrimp per square meter in Johnson Key Basin; 7 shrimp per square meter in south central Florida Bay (when western monitoring area exceeds 15 shrimp per square meter); 5 shrimp per square meter in Whipray Basin at least (when western monitoring area exceeds 15 shrimp per square meter); 7 shrimp per square meter in outer bays (Ponce de Leon Bay) (when western monitoring area exceeds 15 shrimp per square meter); and 2 shrimp per square meter in nearshore optimal habitat from Shoal Point to Turkey Point (South Biscayne Bay).

## Why is this indicator important?

The pink shrimp is ecologically important in Florida Bay and Biscayne Bay as a major link between the food web base and top consumers, including game fish and wading birds. The life cycle is best known for pink shrimp using Florida Bay as a nursery ground. They spawn offshore near the Dry Tortugas, migrate shoreward as larvae/postlarvae, and settle in seagrass beds in Florida Bay to spend their juvenile stage before returning to offshore spawning grounds, where they support a multimillion dollar fishery. Juvenile pink shrimp are present in coastal waters throughout South Florida. Juvenile densities are highest in western Florida Bay (Costello et al. 1986, Robblee et al. 1991, M. Robblee personal communication). Biscayne Bay supports small local fisheries for food shrimp and bait shrimp, operating within the bay. The mangrove estuaries of the southwest coast also provide nursery area for pink shrimp; however, limited sampling with the same gear (throw-trap) used in Florida Bay (Rice 1997, Browder et al. 1999) suggest juvenile densities are lower in the mangrove estuaries.

The potential for improving shrimp nursery habitat in Florida Bay may be greatest in the north-central bay, where water management changes associated with the CERP could potentially reduce the frequency, spatial extent, and duration of hypersaline conditions. A target for eastern Florida Bay is not provided because shrimp densities are extremely low, are thought to have been low historically, and are not expected to change with CERP implementation. Based on present knowledge (Robblee and Browder 2003), pink shrimp densities are not expected to be as great in Biscayne Bay as in Florida Bay. Postlarval settlement rates may differ in the two areas, and they may respond differently to a change in water management associated with any one component of the CERP.

## How will the interim goal for this indicator be predicted?

At each 5-year evaluation interval (2010, 2015, etc.), average pink shrimp peak density between August-October in three areas of Florida Bay will be simulated for each year of the period 1965-2000 using a model of growth and survival as a function of salinity and temperature (Browder et al. 2002). Input data will be the output of multiple linear regression models that relate salinity to freshwater stages at upstream sites in the Everglades, as simulated by the South Florida Water Management Model (SFWMM) hydrologic model for the same period (1965-2000). Density in optimal habitat will be calculated based on average density, the area of each habitat type, and the relationship of pink shrimp density to habitat, as determined from data collected by Robblee et al. (unpublished). Simulations will assume that the area of each habitat will be constant throughout the simulation period (or, alternatively, it might be variable with time and provided as the output of a seagrass landscape model). The biggest year-to-year differences are expected in the north-central bay because this area frequently experiences hypersaline conditions, which have a detrimental effect on production. The frequency of densities above indicated targets during the 36-year simulation period will be determined for each fifth-year evaluation (Figure 13). To take into account annual variation in spawning strength and immigration of postlarvae to the bay from offshore grounds, predicted densities in each area will be evaluated in relation to densities in western Florida Bay. For example, the frequency that targets are met in the north-central and south-central bay (e.g., 15 out of 36 years) will be examined as their ratio to the frequency that targets are met in western Florida Bay (e.g., 28 out of 36 years) (Figure 14).

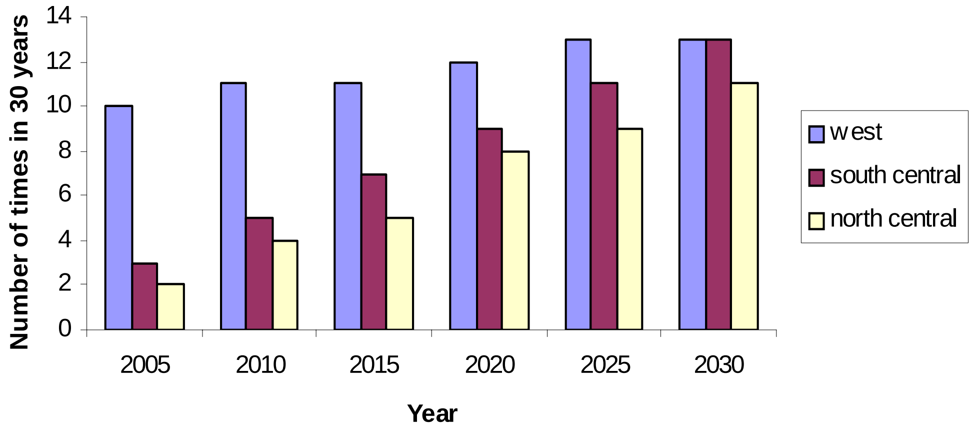


**Figure 13.** Example of model output for frequency of reaching target

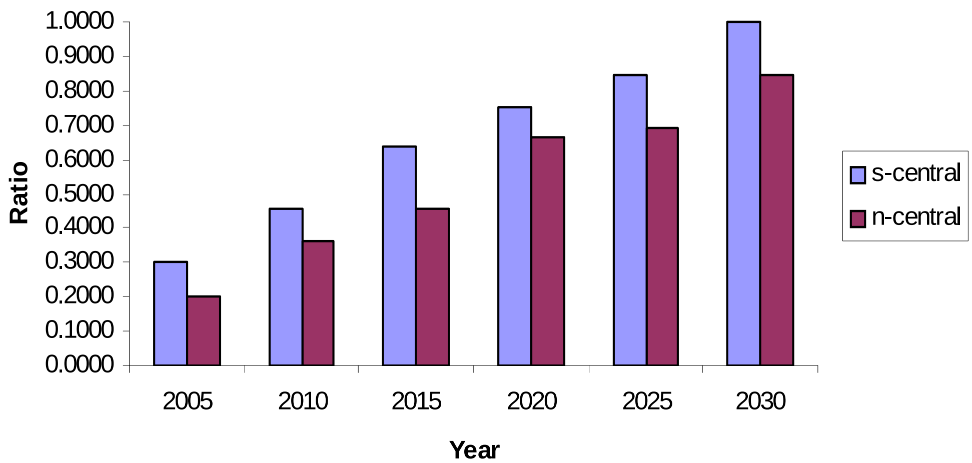


**Figure 14.** Example of model output for ratio of frequencies for meeting target. Note: This graph will be accompanied by a table of results.

### How will we track whether the goals established for this indicator have been achieved?

Juvenile shrimp densities in each of the five areas will be sampled in the August-October period under the *CERP Monitoring and Assessment Plan*. Peak field-measured densities within the August-October period will be compared to model predictions at five-year intervals. These results will be evaluated in relation to goals and compared to 1) model predictions for interim goals and 2) model predictions under daily salinity during the approximate 3-month period immediately preceding sampling.

### What additional work is needed to improve this interim goal?

Time-series predictions of salinity in relation to indices of freshwater inflow to the coast (e.g., stages predicted by the SFWMM or other hydrologic model) are needed as input to the pink shrimp model to predict densities under alternative scenarios. While daily predictions are preferred, weekly or monthly salinity predictions can be used. The output of regression models (Marshall 2003) and basin models (Nuttle 2003) can be used as input to the pink shrimp model in the near term, to be replaced by the output of hydrodynamic models when these models become available.

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# INDICATOR G2.9 - SUBMERGED AQUATIC VEGETATION IN THE NORTHERN ESTUARIES

## What is the restoration goal?

The overall goal is to improve the spatial and structural characteristics of submerged aquatic vegetation (SAV) communities in the northern estuaries.

## Why is this indicator important?

SAV beds form a prominent component of the northern estuaries. SAV meadows provide habitat for many benthic and pelagic organisms, stabilize sediments and can form the basis of detrital food chains. SAV communities are sensitive to changes in salinity and water quality. SAV species composition, abundance and spatial distribution are affected by spatial and temporal salinity patterns and nutrient and light levels. Freshwater inflow patterns (quantity, timing and distribution) affect salinity, nutrients and light. CERP projects that will improve the timing, volume and spatial distribution of freshwater inflows and water quality improvements are expected to enhance SAV spatial coverage of suitable habitat.

## How will the interim goal for this indicator be predicted?

Short-term evaluations will include geographic information system (GIS) applications that identify potential SAV habitat based on factors such as: suitable substrate, salinity and depth (URS Greiner Woodward Clyde 1999). Additionally, a mass based model for *Vallisneria americana* in the Caloosahatchee Estuary will predict shoot counts per square meter based on light, temperature, and salinity. Similar mass based predictive models will be developed for the Indian River Lagoon and Loxahatchee Estuaries. Predictions of biomass based on light and salinity will be made. Data from monthly monitoring will be used to develop and calibrate the models. Ultimately hydrodynamic water quality models linked with SAV models will be used to refine predictions. At this time, limited predictions of future performance of *Vallisneria* can be made. Predictions for other SAV species currently are not possible.

Status and trends in seagrass coverage, density, etc., will be presented in the form of maps, graphs and tables with supporting text.

## How will we track whether the goals established for this indicator have been achieved?

Reporting of percent cover and relative abundance of SAV (*Halodule*, *Thalassia*, *Vallisneria*, *Syringodium*) will be based on field transect monitoring. Reporting of spatial distribution and extent (coverage) of SAV will be based on interpretation of aerial photographs or hydroacoustic monitoring.

## What additional work is needed to improve this interim goal?

Restoration targets have not been set for all northern estuaries. Although preliminary targets have been proposed for the southern Indian River Lagoon (1.7 meter depth target) and St. Lucie Estuary (coverage estimate based on a GIS analysis of “postproject” salinity, suitable substrate, and depth less than 1 meter [SJRWMD and SFWMD 2002]) additional work is needed over the next few years to refine these targets. Targets for the other northern estuaries will be evaluated over the next few years.

Predictive SAV models are currently not available for the northern estuaries. A mass based model being developed for *Vallisneria americana* in the Caloosahatchee River is being considered for use in the other northern estuaries for additional SAV species. It is anticipated that data from the mass based model will eventually be extrapolated to predict spatial coverage using GIS applications. Ultimately the SAV model/GIS applications will be linked to hydrodynamic water quality models to refine predictions. Time frames for developing these predictive tools vary by estuary, but are expected to be developed for all northern estuaries within the next five years.

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## INDICATOR G3.1 – AQUATIC FAUNA REGIONAL POPULATIONS IN GREATER EVERGLADES WETLANDS

### What are the restoration goals?

The restoration goals for aquatic fauna regional populations is 1) achieve late wet season population densities, size distributions and taxonomic compositions of marsh fishes and other selected groups of aquatic fauna consistent with predrainage hydrologic and salinity patterns in the Greater Everglades Wetlands, 2) shift the distribution of high population densities and larger size classes from artificially impounded areas of the Water Conservation Areas to persistent pools to be restored in the oligohaline zone of the southern Everglades, and 3) provide high-density patches of prey-availability across the greater Everglades landscape where wading birds can feed effectively as water levels recede during the dry season.

### Why is this indicator important?

Understanding the effects of the CERP on the prey bases for wading birds and other higher consumers requires monitoring the regional populations of fishes and other aquatic fauna that are produced during each wet season and the distribution of those populations across the Greater Everglades Wetlands. The aquatic fauna that are anticipated to channel most of the energy to higher vertebrates under restored conditions include fish, crayfish, grass shrimp and aquatic amphibians. Understanding the effects of the CERP on the prey bases for wading birds and other higher vertebrates also requires monitoring the concentration of fishes and other aquatic fauna in high-density patches where the birds can feed effectively as water levels recede during the dry season.

### How will the interim goal for this indicator be predicted?

Sufficient data is not available from many of the landscape subregions of the Greater Everglades Wetlands to establish quantitative relationships between aquatic fauna population densities and concentrations to hydrology and salinity patterns. These relationships will be developed using models based on the first five years of monitoring of the pre-CERP reference condition. Intermediate-scale population models for marsh fishes and other selected groups of aquatic fauna will be developed based on the first five years of monitoring of the pre-CERP reference condition.

Predictions for the indictors of aquatic fauna regional populations will be presented geographically as color-coded maps of the Greater Everglades Wetlands with the distribution of density, biomass and size classes by landscape subregion for major groups of taxa. Comparisons will include the pre-CERP reference condition, restoration targets based on Natural System Model and five-year increments of hydrologic restoration between the two.

### How will we track whether the goals established for this indicator have been achieved?

Field monitoring of marsh fishes and other aquatic fauna will provide information for providing assessments of the interim goal at 5-year intervals.

# INDICATOR G3.2 – SYSTEM-WIDE WADING BIRD NESTING PATTERNS

## What is the restoration goal?

The goal of the CERP is to recover healthy populations of wading birds throughout the greater Everglades basin (total system). Wading bird population health is determined by system-wide patterns of nesting, and includes measurements of four variables: numbers of nesting birds, locations of nesting colonies, timing of nesting and frequency of "supra-normal" colonies.

Endpoint restoration goals for each species have yet to be refined. In general, however, the goal for numbers of nesting pairs is for a substantial increase above the pre-CERP numbers that have occurred for a period of record between the 1986 and 2005 nesting seasons.

For the locations of nesting colonies, the goal will be a substantial increase in nesting by egrets, ibis and storks in the region of the southern Everglades mainland estuaries. An initial goal for these species will be a return to greater than 50 percent of nesting pairs in the estuarine region compared to less than 10 percent under current conditions. For spoonbills, the goal will be a realignment of nesting colonies into eastern Florida Bay.

The goal for timing of nesting will apply primarily to the Wood Stork. The timing goal will be for storks to initiate nesting no later than January 31 in most years. Storks have been initiating nesting as late as February and March in most recent years.

For supra-normal breeding events, the goal is to recover predrainage patterns of super colony nesting events. The restoration goal has yet to be refined, but in general is to have about two supra-normal breeding events during each 10-year time period ( less than one event per decade since the 1970s).

## Why is this indicator important?

The selection of wading bird indicators, as well as the predictions of responses by wading birds to the implementation of the CERP, is based on a set of working hypotheses presented in the Total System Conceptual Ecological Model (Ogden and Barnes in prep.). These working hypotheses explain the linkages between changes in hydrological patterns and changes in wading bird nesting patterns.

Wading birds have historically been abundant and widely distributed components of the Greater Everglades Wetlands. Because much is known of their habitat requirements and historical nesting patterns, they are excellent indicators of the system-wide health of the Everglades ecosystem. The number of wading birds that nested in the freshwater and estuarine Everglades basin declined by about 90 percent between the early 1930s and the 1980s. Primarily since the 1960s, most wading birds abandoned the traditional colony sites in the estuaries of the southern Everglades. Roseate Spoonbills have relocated colony sites in Florida Bay in response to water management practices on the upstream mainland. Wood Storks changed the timing of nesting during this same period of years, delaying nesting 1-3 months compared to the earlier period. The extremely large "supra-colonies" that formed on average every 4-5 years during the 1930s-1940s had largely disappeared after the 1960s. These changes in nesting patterns were largely caused by adverse water management and land use practices.

## How will the interim goal for this indicator be predicted?

Still to be worked out is how we will determine and report among-year variability in nesting numbers, and whether nesting patterns during the past 1-2 decades have shown trends for the indicator species. Although initial predictions will be by best professional opinion, it is currently assumed that wading bird nesting patterns will not have changed due to any influences by the CERP as early as the first reporting period in 2010. The team will use 1) the predicted regional hydropatterns developed during the 5-year incremental South Florida Water Management Model (SFWMM) modeling of the CERP implementation plan, 2) outputs from habitat suitability indices models for prey abundance and availability, and 3) current hypotheses and understandings of relationships among nesting patterns, prey availability and regional hydropatterns as a basis for predicting the timing and direction of changes in nesting patterns.

Predictions for supra-normal nesting events will be by best professional opinion, although some additional analysis of pre-CERP nesting patterns will be required as a basis for making such predictions. The team will use output from the SFWMM simulation of the CERP implementation schedule as a basis for the predictions. Current hypotheses propose that more natural patterns of supra-normal nesting events may reoccur once predrainage cycles of multiyear wet-dry surface water patterns, and more normal sheet flow patterns, are recovered in the regional, freshwater Everglades system.

### How will we track whether the goals established for this indicator have been achieved?

We will report on annual, system-wide total numbers of nesting pairs for each of five species: Great Egret, Snowy Egret, White Ibis, Roseate Spoonbill, and Wood Stork. The numbers of nesting pairs for each species will be reported as 3-year running averages, and will be updated annually.

A comparison will be provided of the number and size of colonies, and the percentage of total nesting for each species, in each of several subregions: Everglades mainland estuaries (the traditional nesting subregion in southern Everglades National Park); interior Everglades including the Water Conservation Areas; Lake Okeechobee basin; Big Cypress basin; Gulf Coast estuaries; and Florida Bay. Maps will be used to show annual colony locations.

The timing of initiation of nesting by Wood Storks in Everglades and Big Cypress colonies will be reported annually.

The interval of years between regionally scaled, supra-normal breeding events (measured at regional rather than colony scale) will be reported. Supra-normal events are defined as years in which the number of nesting birds (all species) is greater than one standard deviation above the long-term mean of nesting.

### What additional work is needed to improve this interim goal?

The wading bird development team is not aware of any existing numerical models that can be used to predict nesting pattern responses by wading birds to large-scale manipulations and restoration of regional surface hydropatterns. The team will review the current status of the ATLSS wading bird models to determine if these models will eventually meet these needs. At present, the development team is much more confident that it can predict the timing and direction of trends for the selected wading bird indicators than it can predict numerical responses by wading birds at any given time in the future.

### References

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## INDICATOR G3.3 - RECOVERY OF THREATENED AND ENDANGERED SPECIES AND SUPPORTING HABITATS - AMERICAN CROCODILE

### What is the restoration goal?

The restoration goal for American crocodiles is establish appropriate salinity regimes for optimal growth and survival of juvenile crocodiles.

### Why is this indicator important?

American crocodiles rely on healthy estuarine environments characterized by appropriate salinity regimes and freshwater inflows (Mazzotti 1999); therefore, crocodiles can be used to evaluate restoration success in estuaries affected by the CERP. Several laboratory and field studies have been conducted that investigate the relationship of salinity to growth and survival in juvenile American crocodiles (Ellis 1981, Mazzotti et al. 1986, Dunson and Mazzotti 1989, Mazzotti and Brandt 1995, Richards 2003). Most of these studies have reported a negative relationship between salinity and growth rate, particularly in hatchling and juvenile crocodiles. Although depredation is the primary documented cause of mortality in hatchling and juvenile crocodiles in Florida (Kushlan and Mazzotti 1989), increased growth rates are hypothesized to result in increased survival rates of hatchling crocodiles (Thorbjarnarson 1989), though this relationship has not been empirically tested. Because the CERP will affect salinity in habitats occupied by crocodiles, reduced salinity is expected to increase the productivity of prey and allow for increased juvenile crocodile growth through greater prey availability.

### How will the interim goal for this indicator be predicted?

The prediction of reduced salinity within crocodile habitat, especially nursery habitats where hatchling and juvenile crocodiles are most likely to occur, will be based on simulations of flow and salinity generated by the U.S. Geological Survey Southern Inland and Coastal System Project (SICS). The current version of the SICS model represents a 5-year period from January 1995 to December 1999 and comparisons between observed and simulated values of flow, stage and salinity suggest that this model provides a good representation of the physical system, although additional effort is needed to be able to use the model to evaluate the effects of the CERP in coastal wetlands and South Florida estuaries (Langevin et al 2003). An indicator region will be selected within nursery habitats adjacent to documented and suitable nesting areas within the model domain. Salinity-duration curves and will be generated for these regions, and increased hatchling crocodile growth and survival will be expected within those areas showing the greatest reduction in salinity and duration of low salinity during the primary growth period for hatchling American crocodiles (July-November; Mazzotti 1989, Moler 1991). Because the calibrated SICS model only represents a 5-year period of record, conditions will be modeled separately for each 5-year evaluation period, and assumes completion of CERP project features as scheduled. Boundary conditions for expected future conditions will include canal flows and stages at South Florida gages that are generated from South Florida Water Management Model (SFWMM) models. Weather patterns (wind and temperature) will be modeled for all simulations as the 1995-1999 period of record for the model domain.

If the SICS model cannot be evaluated to adequately provide a period to prediction of the first 5-year period, two alternative methods are available. The first is to use a different salinity model for Florida Bay such as a mass-balance model. Benefits include a period of record that is more consistent with the SFWMM, and a relatively simple model structure. Disadvantages include a level of spatial generalization that could mask important characteristics and possible limitations in modeling groundwater influences on salinity.

The third approach would provide the lowest resolution and would be the most assumption-laden. In this approach, the SFWMM would be used in conjunction with indicator regions (approximately three cells inland of the model domain boundary). These regions will be identified and modeled stage and flow output will be evaluated as indicative of delivery of fresh water to the estuaries. Regardless of the approach chosen, the SICS model should continue to be calibrated, and should be adopted in the future for evaluating expected salinity and crocodile growth and survival.

### How will we track whether the goals established for this indicator have been achieved?

Juvenile growth rate and survival as related to predicted salinity conditions will be measured at various stations in Everglades National Park as describe in the *CERP Monitoring and Assessment Plan* (Recover 2004).

### What additional work is needed to improve this interim goal?

The ability of the SICS model as a fully hydrodynamic surface-water model allows it to provide a good representation of transport, and thus salinity patterns, in the South Estuaries region (Langevin et al. 2003). However, to date, the SICS model has not been peer reviewed, and calibration of a 7-year (1996-2002) period of record is underway. Additional information needs include evaluation of SICS model output, development of appropriate indicator regions within the SICS model domain, and evaluation of the validity of using SFWMM-predicted canal flows and stages as boundary conditions in SICS model runs of future conditions.

### References

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## INDICATOR G3.4 - SYSTEM-WIDE AMERICAN ALLIGATOR DISTRIBUTION AND ABUNDANCE

### What is the restoration goal?

The restoration goal for American alligators to restore more natural numbers and distribution patterns for alligators across South Florida's major freshwater and estuarine wetland landscapes.

### Why is this indicator important?

Alligators are a keystone species in the South Florida wetlands, in that they play a major role in influencing the overall health and ecological patterns of the region. Regionally, overall numbers of alligators have substantially declined, and distribution patterns greatly altered, as a result of water and land management practices. Overdrained wetlands and reductions in numbers of alligators have caused the loss of many small ponds ("holes") that were essential for the survival of small aquatic animals during dry seasons. It is expected that CERP will result in the recovery of more natural hydropatterns regionally, which in turn will promote the recovery of healthy alligator patterns.

### How will the interim goal for this indicator be predicted?

In the absence of an acceptable computer model, alligator relative abundance and distribution trends would be based on best professional judgment of the South Florida Crocodilian Research Team, which is an informal multi-agency group of researchers working on crocodilians primarily in South Florida. The long-term plan is to use the Alligator Population Model (Slone et al. 2003), which has a resolution of 500 x 500 meters and can be used to look at relative abundance across the landscape and along discrete survey routes that are sampled in the field. Use of this model is dependent on the additional data inputs and resources listed in the Additional Information section below.

### How will we track whether the goals established for this indicator have been achieved?

Parameters to be measured for this interim goal include relative abundance of alligators throughout the ridge and slough Everglades, more natural patterns of sizes of animals, habitat restoration, and the recovery of healthy "populations" in the southern marl prairies and rocky glades, and estuarine rivers and creeks. The metrics used will be 1) alligators per kilometer for creeks and rivers in the ridge and slough and 2) alligators per "gator hole" for marl prairies and rocky glades. The relative densities will be expressed in two ways: all nonhatchling alligators (greater than or equal to 5 meters in length) and adults only (greater than or equal to 1.75 meters in length). Note that there is uncertainty in the actual size that alligators in the Everglades become adults (start to breed). Observations in Everglades National Park (O. Bass pers. comm.) indicate that animals may be breeding at 1.5 meters. Additional captures at nests throughout the system should be conducted to evaluate this observation and modify the expression of the metric if needed.

### What additional work is needed to improve this interim goal?

Validation of the Alligator Population Model requires updated hydrologic data for the period 1995-2000 at 500 x 500 meters. In the past, this information has been obtained from the ATLSS pseudo-topography modeling. In addition, data from the Alligator Production Index from ATLSS are required for the same time period. This task is scheduled to be completed by December. Future versions of the Alligator Population Model will have the ATLSS Alligator Production Index built in.

Additional runs (predictions) of the Alligator Population Model will require hydrologic data on the 500 x 500 meter scale as has been provided by the ATLSS pseudo-topography. These additional runs of the model will require additional resources. Currently, no resources are allocated for updating the model, supporting the model and coding, or conducting runs and analysis associated with Interim Goals. It is estimated that it will cost approximately $25,000 per year in most years for maintenance and improvement to model code, and $50,000 in years when Interim Goals or other extensive analysis are needed. Updating and improving the model will require field work that addresses the uncertainties within the model especially in relation to size at reproduction, changes in clutch size, and juvenile movements and survival.

Alligator holes in the southern marl prairies and rocky glades have to be mapped and characterized to determine patterns of occupancy by alligators.

## References

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# INDICATOR G3.5 - LAKE OKEECHOBEE ECOLOGICAL COMMUNITIES – SUBMERGED AQUATIC VEGETATION

## What is the restoration goal?

The restoration goal for Lake Okeechobee submerged aquatic vegetation (SAV) is maintain healthy communities submerged aquatic vegetation, littoral zone vegetation and shoreline bulrush. Specifically, the following goals apply:

- Maintain at least 40,000 acres of total SAV, and at least 20,000 acres of vascular SAV (eelgrass, peppergrass and southern naiad), as 5-year moving averages of yearly data

- Maintain a substantially increased spatial extent of native, noninvasive plants (e.g., spikerush, beak rush, willow, sawgrass, button bush and pond apple) in the littoral zone

- Maintain at least 5,000 acres of healthy bulrush along the lake's west and north shorelines, as a 5-year rolling average of yearly data

## Why is this indicator important?

A diverse and spatially expansive community of submerged and emergent vegetation in the lake's littoral and shoreline shelf areas provides critical habitat for the nesting and foraging of fish, wading birds, migratory water fowl, and other wildlife that depend on the ecosystem, including the federally-endangered Everglades Snail Kite. This is documented in the Lake Okeechobee Conceptual Ecological Model (RECOVER 2004).

## How will the interim goal for this indicator be predicted?

Presently, no tools are available that provide quantitative predictions about the spatial extent of various plant species as a function of water levels in the lake. A quantitative model is under development to predict spatial distribution and biomass of SAV, using output from the Lake Okeechobee Environment Model. No plans have been made to develop models to make quantitative predictions about responses of emergent littoral plants.

## How will we track whether the goals established for this indicator have been achieved?

The rate and extent to which the acreages of the various plant communities increase towards the established goals will be the benchmark for judging the success of the CERP in restoring those particular ecological functions of the lake.

## What additional work is needed to improve this interim goal?

The relationship between water regimes and emergent littoral vegetation should be further defined through research. Models that predict responses of emergent littoral vegetation should be developed for predicting future goals. Furthermore, only qualitative information is presently available regarding how changes in the plant community translate into increased health of the aquatic fauna. This should be addressed by future research.

## References

RECOVER. 2004. Appendix A: Draft Conceptual Ecological Models. In: RECOVER. CERP Monitoring and Assessment Plan. Restoration Coordination and Verification, c/o United States Army Corps of Engineers, Jacksonville District, Jacksonville, Florida, and South Florida Water Management District, West Palm Beach, Florida.

# INDICATOR G3.6 - AMERICAN OYSTERS IN ESTUARIES

## What are the restoration goals?

The restoration goal for American oysters is restore oyster beds within the St. Lucie, Loxahatchee, Caloosahatchee, southern Biscayne Bay estuaries, and lower Gulf Coast river mouths, including the restoration of habitat function and oyster health in areas that become suitable habitat.

## Why is this indicator important?

The American oyster is an almost exclusively estuarine bivalve mollusk. It is ecologically important because it improves water quality by filtering particles from the water, and serves as prey and habitat for numerous other organisms. Water management and dredging practices have had a major impact on the historical presence, density and distribution of oysters (oyster reefs) within the mesohaline areas of Central and South Florida estuaries. Restoration of more natural freshwater inflows into South Florida estuaries as a result of implementation of CERP projects should provide for beneficial salinity conditions that promote the reestablishment of healthy oyster beds.

## How will the interim goal for this indicator be predicted?

Prediction method will be professional opinion and statistical analysis of temporal trends when sufficient data are available. Maps showing the location of sampling stations in each estuary will be presented along with graphs depicting temporal trends in the various metrics.

## How will we track whether the goals established for this indicator have been achieved?

The interim goal for oysters will be assessed by measuring spat abundance and distribution and the spatial extent of oyster beds and oyster health. The following metrics are proposed in the *CERP Monitoring and Assessment Plan* (RECOVER 2004): spat settlement during the months of peak recruitment, percent of adults live and dead, and adult sizes (live and dead).

A baseline for oysters in each estuary must be established by mapping the existing distribution of reefs/beds, size class distribution, and percentage of alive/dead. Historical distributions, if available, would assist in identifying areas which may have suitable habitat conditions for reestablishment, given predictive changes in the salinity regime with the CERP project. Post CERP implementation, a map of the area including size distribution, percentage alive/dead, and depth of the oyster community should be prepared at various time intervals depending on the existence of oyster reefs prior to CERP implementation. For example, oyster reefs do not currently exist in Biscayne Bay at creek mouths where they occurred historically. It may take 3 to 5 years and the addition of substrate before a map can be produced. Since each estuarine system is different and the life history of oysters in each system is known at varying levels of detail, it may not be necessary to monitor all metrics in all systems.

The monitoring data provide information concerning the health of the oyster population (spat settlement, percent and sizes of live and dead oysters) and the resulting maps will document the aerial extent of oyster coverage. Since these data are provided over time, temporal trends in health and coverage can be evaluated.

## What additional work is needed to improve this interim goal?

In order to provide quantitative, specific goals or targets, a detailed population level model for oysters is required. This model would need to provide predictions of recruitment, growth, and survival of multiple cohorts as a function of hydrologic changes. Such models simply do not exist at the present time.

## References

RECOVER. 2004. CERP Monitoring and Assessment Plan. Restoration Coordination and Verification, c/o United States Army Corps of Engineers, Jacksonville District, Jacksonville, Florida, and South Florida Water Management District, West Palm Beach, Florida.

# INDICATOR G3.7 - FLORIDA BAY ALGAL BLOOMS

## What is the restoration goal?

Sustain good water quality in Florida Bay, minimizing the magnitude, duration, and spatial extent of algal blooms in the bay such that light penetration is sufficient to sustain healthy and productive seagrass habitat. The interim goal for Florida Bay algal blooms is prevent any increase in the intensity, duration or spatial extent of such blooms in Florida Bay or adjacent waters within the Florida Bay and Florida Keys Feasibility Study boundaries.

## Why is this indicator important?

The occurrence of algal blooms in the water column of central and western Florida Bay is a major ecological concern. Such blooms are often associated with nutrient inputs from human activities and can negatively impact the entire ecosystem. In particular, blooms decrease water clarity and decrease the penetration of light through the water. Decreased light penetration, in turn, decreases seagrass bed productivity and the health of this critical habitat. Thus, it is essential that CERP implementation, which is intended to restore the greater Everglades, including Florida Bay, does not increase nutrient inputs such that algal blooms are stimulated and harm the bay.

It is possible that increased freshwater flow through the Everglades toward Florida Bay, as planned by the CERP, could stimulate algal blooms in the bay (CROGEE 2002). Algal (phytoplankton) growth in central and western Florida Bay is frequently limited by the availability of nitrogen (Tomas et al. 1999). Freshwater flow from the Everglades is known to be a major source of nitrogen for the bay (Rudnick et al. 1999). Furthermore, the amount of nitrogen flowing into the bay from this source appears to increase with increasing freshwater flow. It is not certain that quality of this nitrogen (its “bioavailability”), which is contained in dissolved organic compounds, is sufficient to fuel algal blooms, but a positive correlation of chlorophyll concentration in central Florida Bay and annual freshwater discharge has been documented (Brand 2001). Assessment of the bioavailability of Everglades’ nitrogen is part of the *CERP Monitoring and Assessment Plan* (RECOVER 2004) and is underway.

It is desired that CERP implementation result in the restoration of Florida Bay’s salinity regime, critical habitats, and fish and invertebrate populations without compromising water quality as indicated by increased algal blooms.

## How will the interim goal for this indicator be predicted?

Predictions of intensity, distribution, spatial coverage, and duration of Florida Bay algal blooms will be based on a water quality model (part of the Environmental Fluid Dynamics Code Model) that is being developed as a task of the CERP’s Florida Bay and Florida Keys Feasibility Study. Modeling for the prediction of Florida Bay algal blooms will be based on chlorophyll concentration (see below).

## How will we track whether the goals established for this indicator have been achieved?

Monitoring for assessment of Florida Bay algal blooms will be based on chlorophyll concentration, which is an indicator of algal biomass. Components are as follows:

- Frequency of Florida Bay chlorophyll concentrations exceeding regional thresholds (2 ppb in eastern and southern bay, 5 ppb in central bay, 3 ppb in western bay)

- Spatial extent (total area per bay region) where chlorophyll concentrations exceed these thresholds
- Duration (number of weeks per bay region) where chlorophyll concentrations exceed these thresholds

These metrics and associated thresholds are derived from the existing Florida Bay water quality monitoring program (South Florida Water Management District and National Oceanic and Atmospheric Administration) and the *CERP Monitoring and Assessment Plan* (RECOVER 2004).

### What additional work is needed to improve this interim goal?

Causes of algal blooms in Florida Bay are complex, involving multiple sources of nutrient supply, the extent of bay water exchange with adjacent marine waters, grazing of algal cells, and other processes. Successful predictions of the relationship between CERP actions and bay water quality require synthesis of existing data (through modeling) and provision of new data on processes that influence algal blooms.

A predictive water quality model is under development and not yet functional. This model is being developed as part of the CERP's Florida Bay and Florida Keys Feasibility Study and will have the capability of predicting the magnitude, duration, and spatial extent of algal blooms, and assess their relationship to freshwater flow and nitrogen associated with this flow. Water quality models of other estuaries have successfully predicted algal bloom dynamics, but Florida Bay modeling is particularly challenging because of the bay's physical and chemical complexity. Thus, successful water quality predictions for Florida Bay depend on successful hydrodynamic modeling (a task of the feasibility study) and provision of data on critical ecological processes (particularly regarding organic nitrogen bioavailability) by RECOVER, the National Oceanic and Atmospheric Administration's Coastal Ocean Program, and other research programs.

### References

Brand, L. 2001. The transport of terrestrial nutrients to South Florida coastal waters. In: Porter, J.W., and K.G. Porter (eds). The Everglades, Florida Bay, and Coral Reefs of the Florida Keys. CRC Press, Boca Raton, Florida, pp. 361-414.

CROGEE. 2002. Florida Bay Research Programs and Their Relation to the Comprehensive Everglades Restoration Plan. Committee on Restoration of the Greater Everglades Ecosystem, National Academies Press, Washington, D.C.

RECOVER. 2004. CERP Monitoring and Assessment Plan. Restoration Coordination and Verification, c/o United States Army Corps of Engineers, Jacksonville District, Jacksonville, Florida, and South Florida Water Management District, West Palm Beach, Florida.

Rudnick, D.T., Z. Chen, D. Childers, J. Boyer, and T. Fontaine. 1999. Phosphorus and nitrogen inputs to Florida Bay: the importance of the Everglades watershed. Estuaries 99:398-416.

Tomas, C.R., B. Bendis, and K. Johns. 1999. Role of nutrients in regulating plankton blooms in Florida Bay. In: Kumpf, H., K. Steidenger, and K. Sherman. The Gulf of Mexico Large Marine Ecosystem: Assessment, Sustainability, and Management. Blackwell Science, Malden, Massachusetts, pp. 323-337.

# Section 2. Interim Targets

## 2.1 Introduction

Interim Targets are defined in the CERP Programmatic Regulations as "*a means by which the success of the Plan in providing for other water-related needs of the region, including water supply and flood protection, may be evaluated throughout the implementation process*" (DOD 2003). Interim Targets provide a means for tracking Plan performance for reporting on progress made at specified intervals of time towards providing for other water-related needs of the region, and for periodically evaluating the accuracy of predictions of system responses to the effects of the Plan.

Indicators for Interim Targets are based on hydrologic performance measures for water supply and flood protection, the majority of which were used in plan formulation and evaluation during the development of the CERP. These measures are being further refined as planning for the CERP proceeds. Performance measures, and hence the indicators for Interim Targets, are based upon current federal and state law and policy.

## 2.2 How Predictions Will Be Made for Interim Targets

Computer simulation models will be used as tools to predict how the indicators will respond to changes brought about by the CERP. By modeling the indicators at discrete time intervals, an expected level of performance can be predicted and performance milestones can be established throughout the life of the Plan. The process of developing Interim Targets will result in measurable parameters that can be evaluated by a numeric target.

The South Florida Water Management Model (SFWMM) is the primary hydrologic simulation model that will be used in the prediction of Interim Targets. The SFWMM is used to predict targets directly or it may provide boundary conditions, or hydrologic inputs, to another subregional hydrologic model (the Lower East Coast Sub-Regional Model [LECSR]) that will be used to assist in this effort as well. The SFWMM is a regional-scale computer model that simulates the hydrology and the management of the water resources system from Lake Okeechobee to Florida Bay. It covers an area of 7,600 square miles using a mesh of 2-mile by 2-mile cells. The model includes inflows from the Kissimmee River, and both runoff and demands in the Caloosahatchee River and St. Lucie Canal basins. The SFWMM simulates the major components of the hydrologic cycle in South Florida including rainfall, evapotranspiration, infiltration, overland and groundwater flow, canal flow, canal-groundwater seepage, levee seepage and groundwater pumping. It incorporates current or proposed water management control structures and current or proposed operational rules.

The models require input data, termed "assumptions", that govern the outputs, or results, of a given model simulation. Many types of data are needed to run the models, including the following:

- Topography (ground elevation data)
- Rainfall
- Evapotranspiration rates
- Sea level data
- Land use

- Vegetation types
- Irrigation and agricultural demands
- Municipal and industrial water supply demands
- C&SF Project water management system structures, operational rules, regulations and schedules
- Canal stages and flows

The LECSR model is a combination of six county-level models, and is used in water supply and flood mitigation planning for the lower east coast. The scale of this model is finer (704-feet by 704-feet cells) than the SFWMM, enabling a more accurate prediction of meeting other water-related needs with this tool.

## 2.3 How Does Uncertainty Affect the Use and Assessment of Interim Targets?

The RECOVER team recognizes that there are several sources of uncertainty associated with the process of developing, predicting and interpreting Interim Targets. In general, these uncertainties can be grouped into four types, each of which is capable of influencing any prediction. Uncertainties are associated with 1) modeling, 2) scheduling of CERP projects, 3) environmental variability and 4) geo-political change.

### *Model Uncertainty*

All model outputs contain some level of uncertainty or variability (defined as deviations from actual or expected values of predictions). Physical and biological models may contain uncertainty resulting from an incomplete understanding and representation of major processes (Gross and Comiskey 2003). Landscape models contain uncertainty associated with incomplete data and the complexity of the landscape. Uncertainties can also result from imprecise measurements of important physical and biological parameters used in equations that describe processes or initial conditions. In general, the more complex the model structure, the greater the total variation of both observational and simulated data and the less accurate (more uncertain) the prediction (Costanza and Sklar 1985). The degree of uncertainty, accuracy and calibration extent of all the models used to predict Interim Goals will be evaluated according to the criteria that was discussed in the Modeling Uncertainty Report provided to the South Florida Water Management District by Loucks and Stedinger in 1994.

### *CERP Scheduling*

The uncertainties associated with the CERP schedule may include unanticipated legal constraints and lawsuits, construction delays, contractual bottlenecks associated with land purchases, feasibility studies and new technologies, adjustments in schedule brought about by the adaptive management process, and the overall complexity associated with the management of a very large restoration program.

The Interim Targets will assume a particular sequence of CERP projects as defined in the *Master Implementation Sequencing Plan* (USACE and SFWMD 2004), as well as a construction period for each project and a specific "benefit" associated with each project. A change in any one of these three assumptions can alter the timing and effectiveness of restoration. Unfortunately, it is unknown just how indicator performance will respond when sequencing is altered. Any schedule change to a CERP or non-CERP project that is directly influencing the volume, flows or quality of the water to the South Florida ecosystem may noticeably alter any predictions associated with hydrologic and water quality goals and targets. Schedule shifts may also noticeably alter predictions associated with the biological and ecological goals.

### *Environmental Variability*

Interim Targets will assume a particular weather and rainfall pattern when using simulation models. Any changes in climate or climatic variability, sea level, and hurricane frequencies may result in major differences between model predictions based on 1965-2000 conditions and the conditions that actually occur in the future. To account for this uncertainty, in the future, all the models used to predict the Interim Targets with the expected time increments of the Plan will be rerun every five years with the real, updated weather and rainfall data. These revised milestones for Interim Targets will then be compared with actual observations to see if the ecosystem is responding as expected and to make sure that restoration is proceeding in the appropriate direction.

### *Geo-political Change*

Large-scale economic, social or geo-political events may influence large-scale projects such as the CERP as state and federal priorities shift in response to these events. These shifting priorities may present themselves as changes in resource allocations or in the scope of the CERP. Of all the uncertainties, geo-political change is the most unknowable. In the implementation planning process for the CERP and the establishment of Interim goals and Interim Targets, however, we must assume geo-political stability.

## 2.4 How the Interim Targets Will Be Approved

According to the Programmatic Regulations (DOD 2003), RECOVER will provide its recommendations to the United States Corps of Engineers and the South Florida Water Management District by June 14, 2004. In consideration of these recommendations, the Secretary of the Army and the Governor will establish interim targets for evaluating progress towards other water-related needs of the region in consultation with other governmental bodies.

## 2.5 How the Interim Targets Will Be Revised

As stated in the Programmatic Regulations, the established Interim Targets will be reviewed at least every five years to determine if they should be revised. Any revisions will undergo the same development and agreement process as the initial Interim Targets. Revisions will incorporate new information and improved prediction capabilities, and will result in a set of Interim Targets that improves over time. As a result, the expected benefits of the Plan may be refined as understanding increases.

Interim Targets may need to be revised for several reasons. First, as annual data are accumulated and linkages between climate variables, hydrology and water demands are studied, understanding of these processes will increase. This improved understanding combined with observations of specific project effects will enable more accurate predictions of hydrologic response. Additional indicators of other water-related needs may be identified and may be added to or substituted for current indicators.

The models and other tools used to predict success of the Plan will be made more accurate as a direct result of improved understanding of the ecosystem. More detailed models will provide alternative prediction methods. In addition, advances in computer hardware will allow for greater spatial resolution and will provide for the development of more complex (i.e., more complete) models.

## 2.6 Status of the Proposed Indicators for Interim Targets

Table 6 below presents the current list of indicators.

**Table 6.** List of recommended Comprehensive Everglades Restoration Plan Interim Target indicators

| All indicators will be developed into interim targets using established predictive methods |
|---|
| T1.1 Volume – Quantity and Distribution |
| T1.2 Water Supply for the Lower East Coast Service Area |
| T1.3 Water Supply for the Lake Okeechobee Service Area |
| T1.4 Protect the Biscayne Aquifer from Saltwater Intrusion |
| T1.5 Protect the Southern Portion of the Biscayne Aquifer from Saltwater Intrusion |
| T1.6 Flood Control: Root Zone Groundwater Levels in the South Miami-Dade Agricultural Area East of L -1N |
| T1.7 Flood Control: Groundwater Stages for Miami-Dade, Broward, Palm Beach and Seminole Tribe Surface Water Management Basins |
| T1.8 Flood Control: Flood Water Removal Rate for the Everglades Agricultural Area |

## 2.7 References

Costanza, R., and F.H. Sklar. 1985. Articulation, accuracy, and effectiveness of mathematical models: a review of freshwater wetland applications. Ecol. Model. 27:45-68.

DOD. 2003. Programmatic Regulations for the Comprehensive Everglades Restoration Plan; Final Rule. Department of Defense, 33 CFR Part 385, Federal Register, November 12, 2003.

Gross, L., and J. Comiskey. 2003. Sources of Uncertainty for ATLSS models. http://www.atlss.org/cerp_runs/uncertain.html.

Loucks, D.P., and J.R. Stedinger. 1994. Sensitivity and Uncertainty Analysis in Hydrologic Simulation Modeling of the South Florida Water Management District. Report of the Workshop on Reduction of Uncertainties in Regional Hydrologic Simulation Models. School of Civil and Environmental Engineering, Cornell University, Ithaca, New York.

USACE and SFWMD. 2004. Master Implementation Sequencing Plan. United States Army Corps of Engineers, Jacksonville District, Jacksonville, Florida, and South Florida Water Management District, West Palm Beach, Florida.

## 2.8 Indicator Documentation Sheets

The following pages contain the indicator documentation sheets for Interim Goals.

# INDICATOR T1.1 – WATER VOLUME – QUANTITY AND DISTRIBUTION

Please note that this indicator has both an interim goal and interim target associated with it. The interim goal indicator (G1.1) is presented in Section 1.

## What is the water supply target?

The targets for quantity and distribution of water are as follows:

**Total System Water Distribution:** Provide more natural water volume deliveries to the natural areas while providing for the other water-related needs of the region.

**New Available Water:** Provide the volume of water to the natural system that is needed to meet the hydrological restoration targets in each region while providing for other water-related needs.

## Why is this indicator important?

Ecosystem benefits depend on the improvement of water quantity, quality, timing and distribution. The increase in regional storage capacity provided by the CERP will make these hydrologic improvements possible while providing for other water water-related needs by increasing the available source of water.

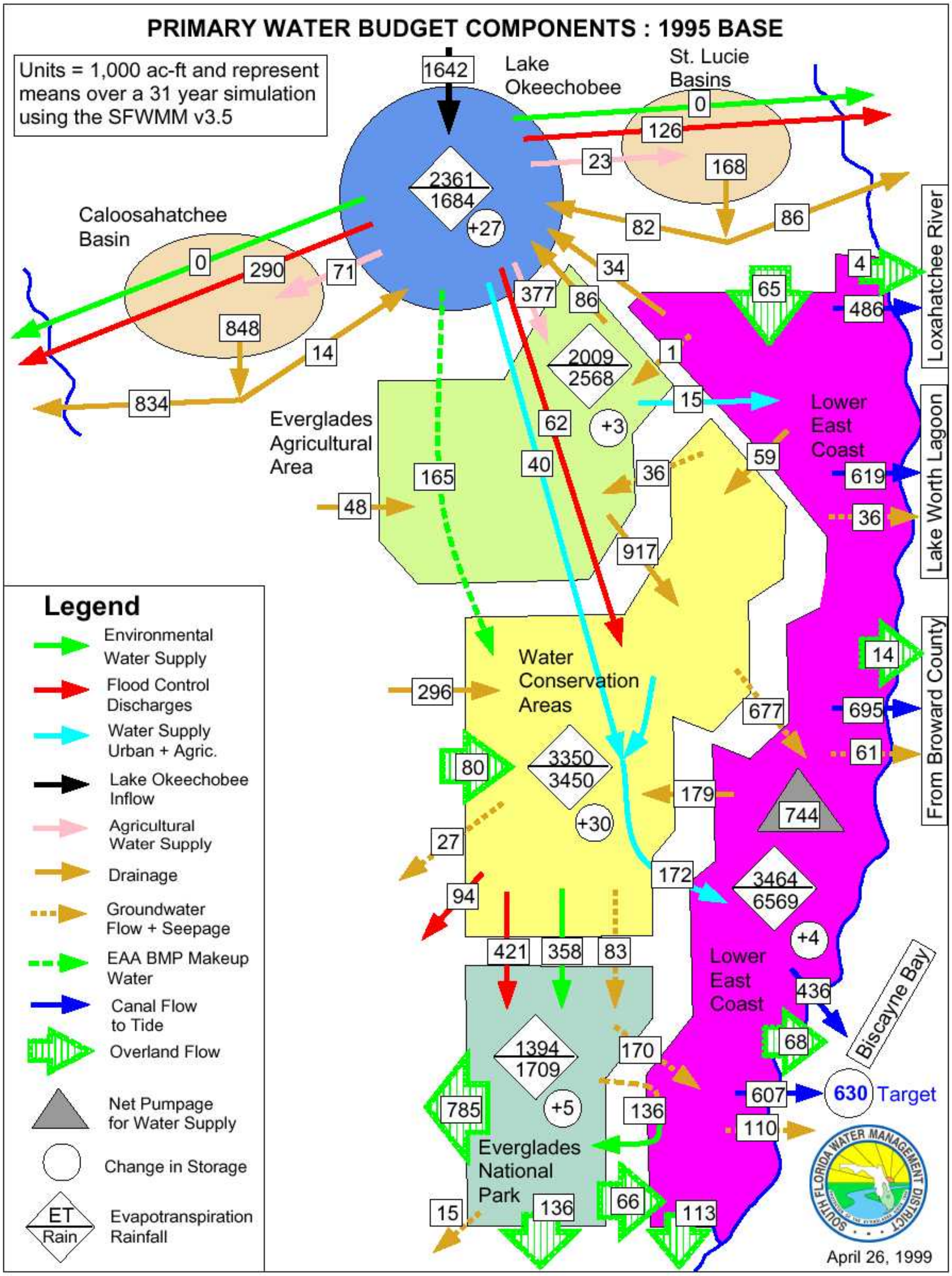
## How will the interim target for this indicator be predicted?

This target is based on South Florida Water Management Model (SFWMM) system-wide water budgets that track water distribution. Using the budgets to set targets provides each region (and, indirectly, many interests) with a set of mutually consistent expectations. In recognition of this, the water budget is used as an interim target. The water budget quantifies the water distribution to basins containing urban and agricultural land uses, and protected natural areas. The Total System Water Distribution goal provides the bulk quantity of water distributed throughout the system and New Available Water goal represents the distribution of the portion of that water that is made available by the CERP.

**Total System Distribution:** This part of the water volume indicator will be used to predict the quantity of water distributed to the natural system in average annual wet season and dry season deliveries. Water budgets provide an excellent way to account for broad changes in water distribution through plan implementation.

Water budget maps based on structure flow data, overland flow, and groundwater flow predicted by the SFWMM will be used to predict the quantity of water distributed within the region. The maps are divided into eight basins: Kissimmee, Lake Okeechobee, Caloosahatchee Canal, St. Lucie Canal, Everglades Agricultural Area, Lower East Coast Service Areas , Water Conservation Areas, Everglades National Park, basin west of Everglades Agricultural Area and Water Conservation Area 3A, Florida Bay, and Biscayne Bay. Figure 15 presents an example of a water budget map. This map is based on the Base 95 Simulation conducted during the C&SF Project Comprehensive Review Study, known as the Restudy, that resulted in the development of the CERP (USACE and SFWMD 1999).

For the interim target calculation, the Water Conservation Areas will be treated as separate basins, unlike the following example. Releases to tide from these basins are given separately for St. Lucie Estuary, Caloosahatchee Estuary, Loxahatchee River, Lake Worth Lagoon, Broward coast, Biscayne Bay and Florida Bay. Net water movement between the basins and from the basins to tide is tracked and identified by arrows on the map; changes in storage are also reported. The distribution of water to and from each basin will be documented by the SFWMM water budget map for each interim year.




1 **Figure 15.** An example of a water budget map based on the Restudy Base 95 simulation.

**New Available Water:** This part of the water volume indicator will predict the increase in volume of water over 2000 existing condition quantities that are available to benefit urban and agricultural users and natural system functions as a result of the CERP. This “new available water” will also be based on the water budget maps, but the calculation is taken one step further by calculating the difference in volumes for a given basin between the interim date and 2000 and posting that quantity as the target for the interim date.

A more detailed description of this calculation involves a matrix used to summarize inflows and outflows to and from each basin for any given simulation (Table 7). The balance of inflows and outflows is compared between two simulations to provide the increase or decrease in storage within a basin (Table 8). For instance, the interim target might be set as an increase in storage of X acre-feet (ac-ft) from 2000 to 2015 in the Everglades Agricultural Area. In this way, incremental steps toward Plan implementation can be tracked through the interim model simulations. Any increases in storage represent “new available water” provided by one simulation over another by redistributing the water in the system. The sum of the changes in storage must always be zero; some basins show a loss of storage while others show a gain. Generally, interior basins show increases and estuaries show losses indicating the flood releases that the CERP captures. The indicator will treat the Water Conservation Areas separately, though they are shown as one basin in these example tables.

### How will we track whether the targets established for the indicator have been achieved?

Field observations of stage and structure flow can be used to determine whether the actual distribution of water matches the predicted distribution of water. In order to provide a more complete analysis of water distribution in terms of interannual variability, the regional model will be used to simulate the projects as they were actually constructed. Water budgets will be recalculated to further determine the extent to which the Plan is meeting expectations.

### What additional work is needed to improve this interim target?

As the regional hydrologic models are improved, this target will be revised.

**Table 7.** 1995 Base inflows and outflows from each basin

| | Outflows From | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Kissimmee | Lake Okeechobee | Everglades Agricultural Area | Water Conservation Areas | Lower East Coast | Everglades National Park | West of Everglades Agricultural Area and Water Conservation 3A | Caloosahatchee | St. Lucie | Everglades Agricultural Area Reservoirs | Caloosahatchee Reservoirs | St. Lucie Reservoirs | Lake Okeechobee Reservoirs | Lower East Coast ASR | Lower East Coast Reuse | North Reservoirs | **Total Inflows** | **Balance (inflows-outflows)** |
| **Inflows To** | Kissimmee | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -1642 |
| | Lake Okeechobee | 1642 | 0 | 86 | 0 | 0 | 0 | 0 | 14 | 82 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1824 | 670 |
| | Everglades Agricultural Area | 0 | 377 | 0 | 36 | 0 | 0 | 48 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 461 | -542 |
| | Water Conservation Areas | 0 | 267 | 917 | 0 | 238 | 0 | 376 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1798 | -70 |
| | Lower East Coast Service Areas | 0 | 0 | 0 | 849 | 0 | 236 | 0 | 0 | 65 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1150 | -2407 |
| | Everglades National Park | 0 | 0 | 0 | 862 | 70 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 932 | -240 |
| | West of Everglades Agricultural Area and Water Conservation Area 3A | 0 | 0 | 0 | 121 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 121 | -303 |
| | Caloosahatchee Canal | 0 | 71 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 71 | -777 |
| | St. Lucie Estuary Canal | 0 | 23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 23 | -210 |
| | Florida Bay | 0 | 0 | 0 | 0 | 113 | 936 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1049 | 1049 |
| | Biscayne Bay | 0 | 0 | 0 | 0 | 1221 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1221 | 1221 |
| | Caloosahatchee Canal to Tide | 0 | 290 | 0 | 0 | 0 | 0 | 0 | 834 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1124 | 1124 |
| | St. Lucie Canal to Tide | 0 | 126 | 0 | 0 | 0 | 0 | 0 | 0 | 86 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 212 | 212 |
| | Palm Beach/Broward to Tide | 0 | 0 | 0 | 0 | 1915 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1915 | 1915 |
| | Everglades Agricultural Area Reservoirs | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Caloosahatchee Reservoirs | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | St. Lucie Reservoirs | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Lake Okeechobee Aquifer Storage and Recovery (ASR) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Lower East Coast ASR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Lower East Coast Reuse | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | North Reservoirs | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Total Outflows** | | 1642 | 1154 | 1003 | 1868 | 3557 | 1172 | 424 | 848 | 233 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11901 | |

**Table 8.** Example of calculation to determine the change in storage within each basin

| Basin | 1995 | Full CERP Performance | Change in Storage |
|---|---|---|---|
| Kissimmee | -1,640 | -1,540 | 100 |
| Lake Okeechobee | 670 | 730 | 60 |
| Everglades Agricultural Area | -540 | -440 | 100 |
| Water Conservation Areas | -70 | -100 | -30 |
| Lower East Coast Service Areas | -2,400 | -2,010 | 390 |
| Everglades National Park | -240 | -210 | 30 |
| West of Everglades Agricultural Area and Water Conservation 3A | -300 | -270 | 30 |
| Caloosahatchee Canal Basin | -780 | -770 | 10 |
| St. Lucie Canal Basin | -210 | -670 | -460 |
| Florida Bay | 1,050 | 1,350 | 300 |
| Biscayne Bay | 1,220 | 1,070 | -150 |
| Caloosahatchee Canal to Tide | 1,120 | 570 | -550 |
| St. Lucie Canal to Tide | 210 | 560 | 350 |
| Palm Beach/Broward Coast to Tide | 1,920 | 1,480 | -440 |
| Everglades Agricultural Area Reservoirs | 0 | 30 | 30 |
| Caloosahatchee Reservoirs | 0 | 140 | 140 |
| St. Lucie Reservoirs | 0 | 10 | 10 |
| Lake Okeechobee ASR | 0 | 130 | 130 |
| Lower East Coast ASR | 0 | 130 | 130 |
| Lower East Coast Reuse | 0 | -260 | -260 |
| North Reservoirs | 0 | 80 | 80 |

## References

USACE and SFWMD. 1999. Central and Southern Florida Project Comprehensive Review Study Final Integrated Feasibility Report and Programmatic Environmental Impact Statement. United States Army Corps of Engineers, Jacksonville District, Jacksonville, Florida, and South Florida Water Management District, West Palm Beach, Florida.

# INDICATOR T1.2 - WATER SUPPLY FOR THE LOWER EAST COAST SERVICE AREA

## What is the target?

This interim target is to meet existing and future municipal, industrial and agricultural water supply needs in the Lower East Coast Service Area up to a 1-in-10 year drought event (Section 373.0361, Florida Statutes [F.S.]). The characteristics of water supply to be measured include the frequency and duration that water restrictions are imposed to protect the water resources from serious harm (Section 373.175, F.S.).

## Why is this indicator important?

A goal of CERP is to enhance economic values and social well being. One means to accomplish this is through ensuring adequate water supplies for current and future water users. CERP intends to increase the storage capacity of water in the regional system that can be delivered to the Lower East Coast Service Area. The increase in regional storage capacity provided by the CERP is expected to curtail the probability of water restrictions by supplementing regional and local sources used to prevent saltwater intrusion and diminish demands on Lake Okeechobee and the Water Conservation Areas.

## How will the interim target for this indicator be predicted?

The Lower East Coast Subregional Model (LECSR) simulates a 36-year period, 1965 to 2000, for each future condition that includes simulation of the South Florida Water Management District's Water Shortage Plan (Chapter 40E-21, Florida Administrative Code [F.A.C.]). The key results are presented in the Frequency of Water Restrictions Graphic (Figure 16), which is a table indicating the months (rows) within each year (column) when simulated water shortages occur. Years are "water years", October to September, to correspond to crop cycles and South Florida’s wet and dry seasons. Shortages occur in the Lower East Coast Service Area either because the Supply-Side Management Policy or the Water Shortage Policy has been implemented. This graphic tracks the implementation of both policies. It also tracks months when water shortages would be likely to occur due to implementation of dry season policies by the South Florida Water Management District's Governing Board. Water restrictions are usually continued until the start of the wet season. Since some of these shortages are due to local conditions and are beyond the reach of the regional water system, water restriction years that do not have two or more months caused directly by the Supply-Side Management Policy or the Water Shortage Policy will not be considered a regionally significant water shortage and can be managed on a utility by utility basis.

Separate evaluations are completed for each of the four Lower East Coast Service Areas: Northern Palm Beach County, Service Area 1, Service Area 2, and Service Area 3. Service Area 1 is essentially central and southern Palm Beach County. Service Area 2 includes Broward County and a small portion of northern Miami-Dade County as well as the Seminole’s Hollywood reservation. Service Area 3 contains Miami-Dade and Monroe Counties.

Additional information is required. This information includes daily stage hydrographs of the cells corresponding to the trigger well locations, Lake Okeechobee weekly stage hydrograph, water year summary of Lower East Coast Service Area water restriction events, regional water deliveries to the Lower East Coast, and average annual Lake Okeechobee inflows and outflows report.

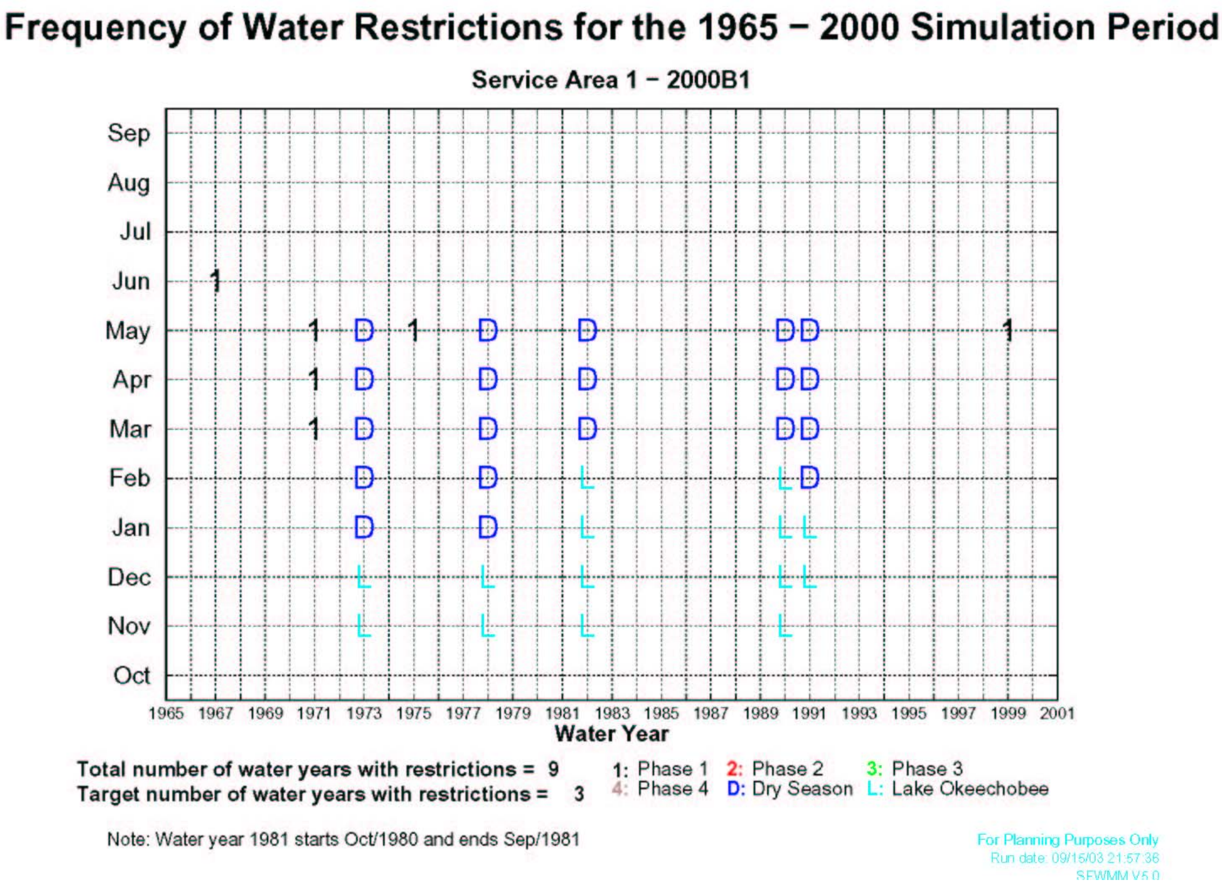



**Figure 16.** Frequency of Water Restrictions Graphic for the Lower East Coast Service Area

### How will we track whether the targets established for this indicator have been achieved?

The number of times and duration when water supply restrictions are imposed will be analyzed to determine if water supply demands were met. If they were not met, determine the severity of the drought associated with the restrictions.

### What additional work is needed to improve this interim target?

No additional work is needed at this time.

### References

Chapter 40E-21 Florida Admininstrative Code. Water Shortage Plan. South Florida Water Management District.

Section 373.0361, F.S. Regional Water Supply Planning. In: Title XXVIII: Natural Resources; Conservation, Reclamation, and Use, Chapter 373: Water Resources, Florida Statutes.

Section 373.175, F.S. Declaration of Water Shortage; Emergency Orders. In: Title XXVIII: Natural Resources; Conservation, Reclamation, and Use, Chapter 373: Water Resources, Florida Statutes.

## INDICATOR T1.3 – WATER SUPPLY FOR THE LAKE OKEECHOBEE SERVICE AREA

### What is the target?

This interim target is to meet existing and future municipal, industrial and agricultural water supply needs in the Lake Okeechobee Service Area up to a 1-in-10 year drought event (Section 373.0361, F.S.). The characteristics of water supply to be measured include the frequency and duration of water restrictions that are imposed to protect the water resources from serious harm (Section 373.175, F.S.).

### Why is this indicator important?

A goal of the CERP is to enhance economic values and social well being. One means to accomplish this is through ensuring adequate water supplies for current and future water users. The CERP intends to increase the storage capacity of water in the regional system for delivery to the Lake Okeechobee Service Area. The increase in regional storage capacity provided by the CERP is expected to curtail the probability of water restrictions by supplementing regional and local sources and diminish demands on Lake Okeechobee.

Pursuant to Sections 373.175 and 373.246, F.S., the South Florida Water Management District (SFWMD) implements water shortage restrictions to prevent serious harm to the water resources and to equitably distribute available water supplies to consumptive and nonconsumptive users. These types of restrictions may be used for the purpose of managing water supplies in Lake Okeechobee as outlined in Rule 40E-21, F.A.C. The specific guidelines for implementing these water restrictions based on water use type and severity of drought are provided in the SFWMD Water Shortage Plan. As part of this overall plan, the Supply-Side Management protocol outlined in this document is designed as a guideline for implementing water use restrictions and management alternatives during declared water shortages. The specific method for implementing restrictions will be determined through Governing Board order.

The Lake Okeechobee Service Area includes those areas surrounding the lake that are directly supplied by it. This includes the Everglades Agricultural Area, Seminole Indian (Brighton and Big Cypress) Reservations, Caloosahatchee Basin, St Lucie Basin, the S-4 Basin and the L-8 Basin. Supplies to these basins include primarily water for agricultural production and public consumption.

### How will the interim target for this indicator be predicted?

The South Florida Water Management Model (SFWMM) is used to simulate a 36-year period, 1965 to 2000, for each future condition and the implementation of the District's Lake Okeechobee Supply-Side Management Policy and Water Shortage Plan (Chapter 40E-21, F.A.C.). The results are presented in the "Frequency of Water Restrictions" graphic (Figure 17), which is a table indicating the months (rows) within each year (column) when water shortages are simulated. Years are "water years", October to September, to correspond to crop cycles and South Florida’s wet and dry seasons. Three criteria are used to determine if the water restrictions are significant. First, for a month to be included in the count, there must be supply-side restrictions for 7 or more days; second, the reduction in deliveries during the month must be 10 percent or more of the monthly totals; and third, the total reduction in deliveries during the month must exceed 18,000 acre-feet. Any water year with one or more months meeting these criteria is counted as a year with significant supply-side restrictions.

Additional information required includes Lake Okeechobee stage hydrograph, regional water deliveries to the Lower East Coast, annual irrigation supply and demand not met for Seminole Tribe Reservations, mean annual Everglades Agricultural Area/Lake Okeechobee Service Area supplemental irrigation demands and demands not met, S-236, S-4, and 8 Basins and Seminole Tribe mean annual supplemental irrigation demands and demands not met and average annual Lake Okeechobee inflows and outflows report.

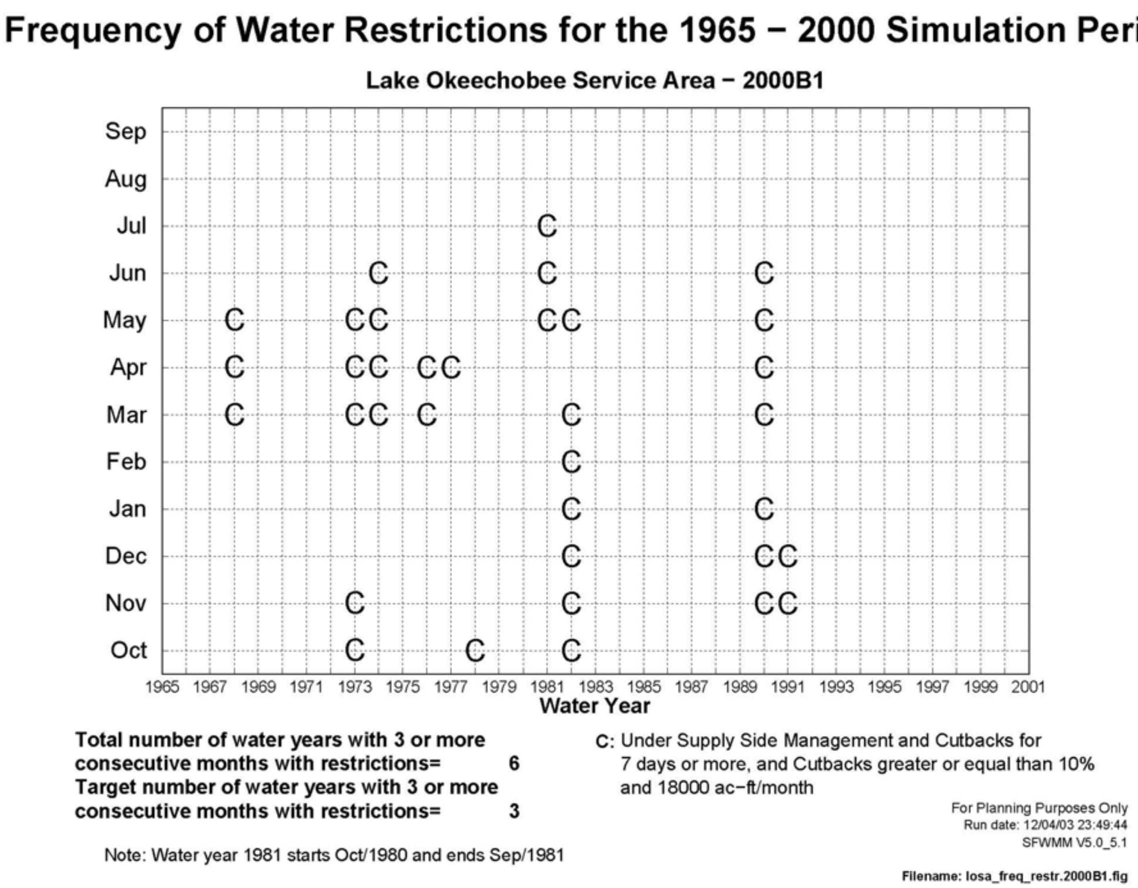



**Figure 17**. Frequency of Water Restrictions Graphic for the Lake Okeechobee Service Area

### How will we track whether the targets established for this indicator have been achieved?

The number of times and duration when water supply restrictions are imposed will be analyzed to determine if water supply demands were met. If they were not met, the severity of the drought associated with the restrictions will be determined.

### What additional work is needed to improve this interim target?

No additional work is needed at this time.

### References

Chapter 40E-21 Florida Admininstrative Code. Water Shortage Plan. South Florida Water Management District.

Section 373.0361, F.S. Regional Water Supply Planning. In: Title XXVIII: Natural Resources; Conservation, Reclamation, and Use, Chapter 373: Water Resources, Florida Statutes.

Section 373.175, F.S. Declaration of Water Shortage; Emergency Orders. In: Title XXVIII: Natural Resources; Conservation, Reclamation, and Use, Chapter 373: Water Resources, Florida Statutes.

## INDICATOR T1.4 - PROTECT THE BISCAYNE AQUIFER FROM SALTWATER INTRUSION

### What is the target?

This interim target has two aspects: a) maintain water levels in the primary coastal canals of the C&SF Project at levels adequate to protect the Biscayne aquifer from significant harm and b) maintain groundwater levels so that there is no net inland movement of the saline interface from inland migration to protect the Biscayne aquifer from harm.

### Why is this indicator important?

A goal of the CERP is to enhance economic values and social well being. One means to accomplish this is through ensuring adequate water supplies for current and future water users by protecting the primary water supply source, the Biscayne aquifer. The CERP intends to increase the storage capacity of water in the regional system for delivery to the Lower East Coast Service Area. The increase in regional storage capacity provided by the CERP will supplement regional and local sources used to prevent saltwater intrusion.

Harm to the Biscayne aquifer in terms of saltwater intrusion is considered to be movement of the saltwater interface to a greater distance inland than has occurred historically as a consequence of seasonal water level fluctuations up to and including a 1-in-10 year drought event.

In order to prevent harmful movement of the saltwater interface in the Biscayne aquifer, the South Florida Water Management District (SFWMD) manages coastal ground water levels by operating the primary canal network, regulating surface water control elevations for developments (through surface water management permitting), and by limiting coastal consumptive use withdrawals. Operational criteria for the coastal canals are maintained by the SFWMD to prevent harm. These actual levels vary seasonally as the SFWMD works to balance the goals of flood protection (wet season control level) and water supply (drought management control level). The drought management control levels represent target management elevations during the dry season. Water supply releases are made from regional storage sources (currently the Water Conservation Areas and Lake Okeechobee) to achieve these targets whenever possible. These canal levels in turn influence the adjacent dry season groundwater elevations within the Biscayne aquifer.

Groundwater levels within the Biscayne aquifer are controlled by local rainfall and by the canals and structures that are regionally operated by the SFWMD. The aquifer system becomes more rainfall driven and less canal dependent as the distance from the canals increases. However, canal water levels play a major role in determining the elevation of the freshwater levels in the Biscayne aquifer throughout most of South Florida. Because of this relationship, the SFWMD maintains operating levels for the primary coastal canals as a means to protect a major portion of the Biscayne aquifer against further saltwater intrusion. These control levels are listed as the “Target Canal Stages” below.

The consumptive use permit conditions for the protection of coastal fresh groundwater dovetail with these canal operational levels by requiring coastal users to maintain a freshwater mound between the withdrawal point and the source of saline water. This is described as follows in the SFWMD Basis of Review document, Volume III, p A-37 (SFWMD 1994):

> Cumulative withdrawals from a fresh water aquifer may only occur in such a manner that a hydraulic barrier between the withdrawal facility or facilities and the source of saline water is maintained. This is

> accomplished through the maintenance of a fresh water mound or ground water divide in the aquifer located between the source of saline water and the point of withdrawal at all times of the year. Staff will not recommend a newly proposed use for approval or an increase in allocation for an existing use under the following circumstances:
>
> A. The hydraulic gradient between the wellfield and saline water is such that a hydraulic gradient (mound of fresh water) less than one foot National Geodetic Vertical Datum (NGVD) exists between the wellfield and saline water source during the months of November through April
>
> B. Monitoring wells within 800 feet of a production well reflect chloride concentration increases at the base of the aquifer, indicating long-term advancement of the saline front toward the wellfield or within the freshwater portions of the aquifer
>
> C. Other evidence shows saline water intrusion will be a serious threat to the wellfield and natural resource if pumpage is allowed or increased (Minimum Flows and Levels - February 29, 2000 Draft Chapter 4: Proposed Minimum Flows and Levels Criteria). Withdrawals of fresh water must not result in significant upconing of saline water.
>
> Significant movement is defined as a movement of one-third of the original distance separating the bottom of the screened or open interval of a production well from the boundary of saline water below it.

These two programs (canal operations and consumptive use permitting) implemented as described above, have been successful in preventing harmful movement of saltwater within the Biscayne aquifer, except for some very localized events in areas where the saltwater interface has not been stable. Studies show that movements of salt water in these areas were most likely the result of drainage associated with land development activities and surface water management systems (Merritt 1996).

### How will the interim target for this indicator be predicted?

The South Florida Water Management Model will be used to simulate a 36-year period, 1965 to 2000, for each future condition for which interim targets will be set. Canal stages will be predicted at the indicated structures. The minimum flow and level criteria to prevent significant harm to the Biscayne aquifer is 180 days and is one criterion for this interim target (SFWMD 2000a) (Table 9).

Primary coastal canals are usually maintained except during droughts or storm events. If stage criteria cannot be met, its timing should correspond with drought.

Additional model output required includes stage hydrographs for canals at selected structures, regional water supply deliveries to Lower East Coast, and stage hydrographs for selected cells.

To predict whether no harm will occur to the Biscayne aquifer, the Lower East Coast Subregional Model will be used. The Lower East Coast Regional Water Supply Plan (SFWMD 2000b) identified the saltwater intrusion criteria as “water use withdrawals should not cause water flows towards the east in the Surficial Aquifer System to be less than the flows west near the saline water interface during a 12-month drought condition that occurs as frequently as once every 10 years. If groundwater flow east towards the coast is less than the flow west, the saline interface has the potential to move.” (SFWMD 2000b) A 1-in-

10 drought event was also identified in the Lower East Coast Regional Water Supply Plan. It begins June 1989 and ends May 1990 for the North Palm Beach Service Area, Lower East Coast Service Area 1 and Lower East Coast Service Area 2. The rainfall defined drought for Lower East Coast Service Area 3 begins and ends one month earlier.

**Table 9.** Minimum flow and level criteria to prevent significant harm to the Biscayne aquifer

| Canal @ Structure | Minimum Canal Operational Levels Needed to Protect Biscayne Aquifer during Drought Conditions (feet NGVD) |
|---|---|
| C-51 @ S-155 | 7.80 feet |
| C-16 @ S-41 | 7.80 feet |
| C-15 @ S-40 | 7.80 feet |
| Hillsboro Canal @ G-56 | 6.75 feet |
| C-14 @ S-37B | 6.50 feet |
| C-13 @ S-36 | 3.80 feet |
| North New River @ G-54 | 3.50 feet |
| C-9 @ S-29 | 2.00 feet |
| C-6 @ S-26 | 2.00 feet |
| C-4 @ S-25B | 2.20 feet |
| C-2 @ S-22 | 2.20 feet |

## How we track whether the targets established for this indicator have been achieved?

The number of times (frequency) the coastal canal stages and the number of consecutive days (duration) the criterion is not met for each event will be monitored and analyzed to determine if it was related to drought conditions or other causes. The monitoring data at the control structures will also be compared to historical conditions and the ability to meet operating criteria.

The SFWMD and the U.S. Geological Survey jointly manage and fund an extensive groundwater monitor well network in South Florida. During the 2002 water year (October 1, 2001 to September 30, 2002), the U.S. Geological Survey monitored 512 wells in southern Florida to assess regional groundwater conditions (Torres pers. comm. 2003). In southeastern Florida, the principal aquifers monitored are the Biscayne aquifer in Miami-Dade and Broward Counties (230 wells) and the Surficial aquifer system in Palm Beach, St. Lucie, and Martin Counties (52 wells). Groundwater stages and chlorides are monitored along the saltwater intruded area and will be analyzed to determine if the saltwater-freshwater interface has moved to a greater distance inland than has occurred historically as a consequence of seasonal water level fluctuations up to and including a 1-in-10 year drought event.

## What additional work is needed to improve this interim target?

An evaluation of the monitoring well network was completed in March 2002 by a SFWMD task force (Lukasiewicz et al. 2002), and the resulting report presents specific recommendations for improvements to this well network. The report concluded that, overall, the total number of wells in the network provides adequate spatial resolution; however, the frequency of water level readings is not sufficient to support future groundwater computer modeling efforts including those being conducted for CERP regional evaluations. Many recent models developed by the SFWMD (to support regional water supply plan development) run on daily time periods because stages in surface water bodies (i.e., canals) vary on a daily basis. The frequency of ground water level monitoring will need to correspond to the daily time periods of the models to ensure adequate model calibration (RECOVER 2004).

In addition, the models applied to simulate groundwater hydrology need to be improved to include density dependent transport functions near the coast to more accurately simulate the saltwater-freshwater interface.

## References

SFWMD. 1994b. Part A: Basis of Review for Water Use. In: South Florida Water Management District. Management of Water Use Permitting Information Manual: Volume III. West Palm Beach, Florida.

SFWMD. 2000a. Minimum Flows and Levels for Lake Okeechobee, the Everglades and the Biscayne Aquifer. South Florida Water Management District, West Palm Beach, Florida.

SFWMD. 2000b. Lower East Coast Regional Water Supply Plan. South Florida Water Management District, West Palm Beach, Florida.

RECOVER. 2004. CERP Monitoring and Assessment Plan. Restoration Coordination and Verification, c/o United States Army Corps of Engineers, Jacksonville District, Jacksonville, Florida, and South Florida Water Management District, West Palm Beach, Florida.

## INDICATOR T1.5 - PROTECT THE SOUTHERN PORTION OF THE BISCAYNE AQUIFER FROM SALTWATER INTRUSION

### What is the target?

This interim target for this indicator is to maintain water levels in the south Miami-Dade coastal canals of the C&SF Project at levels adequate to protect the Biscayne aquifer and stabilize the saline interface.

### Why is this indicator important?

A goal of the CERP is to enhance economic values and social well being. One means to accomplish this is through ensuring adequate water supplies for current and future water users by protecting the primary water supply source, the Biscayne aquifer. The CERP intends to increase the storage capacity of water in the regional system for delivery to the Lower East Coast Service Area. This additional regional water will supplement local water supplies and reduce demands on the natural system. The increase in regional storage capacity provided by the CERP will supplement regional sources used to prevent saltwater intrusion.

Groundwater levels within the Biscayne aquifer are controlled by local rainfall and by the canals and structures that are regionally operated by the South Florida Water Management District. The aquifer system becomes more rainfall driven and less canal dependent as the distance from the canals increases. However, in south Miami-Dade County the soils are relatively thin and canals are cut into the oolite and bryozoan facies of the Miami Limestone and have penetrated into the Fort Thomson Formation in some areas. As a result, these canals are directly connected to some of the most permeable sections of the Biscayne aquifer. It is difficult to maintain canal stages for extended periods of time without using a significant volume of water from regional storage.

Canal water influences the elevation of the freshwater levels in the Biscayne aquifer in south Miami-Dade County. To the extent possible, the SFWMD maintains operating levels in south Miami-Dade coastal canals as a means to protect portions of the Biscayne aquifer against further saltwater intrusion. These control levels are listed as the “Target Canal Stages” in Table 10 (SFWMD 2000a).

**Table 10.** 2000 base canal stages

| Canal @ Structure | Target Canal Stages (feet NGVD) |
|---|---|
| C-100A@ S-123 | 2.00 feet |
| C-1@ S-21 | 2.00 feet |
| C-102 @ S-21A | 2.00 feet |
| C-103 @ S-20F | 2.00 feet |

### How will the interim target for this indicator be predicted?

The Lower East Coast Sub-Regional Model (LECSR) will calculate weekly stages for primary coastal canals for each of the 5-year interim model runs subsequent to 2000. The LECSR can indicate whether changing hydrologic conditions have increased or reduced simulated canal stages as compared to the 2000 base. The model should be used to compare relative differences between alternatives as opposed to absolute differences. For this exercise, the stage for the 2000 existing condition in the 36-year period of rainfall conditions from 1965 through 2000 will be used as the indicator of whether the stage duration has increased or reduced at the 50th and 90th percentiles (Figure 18).

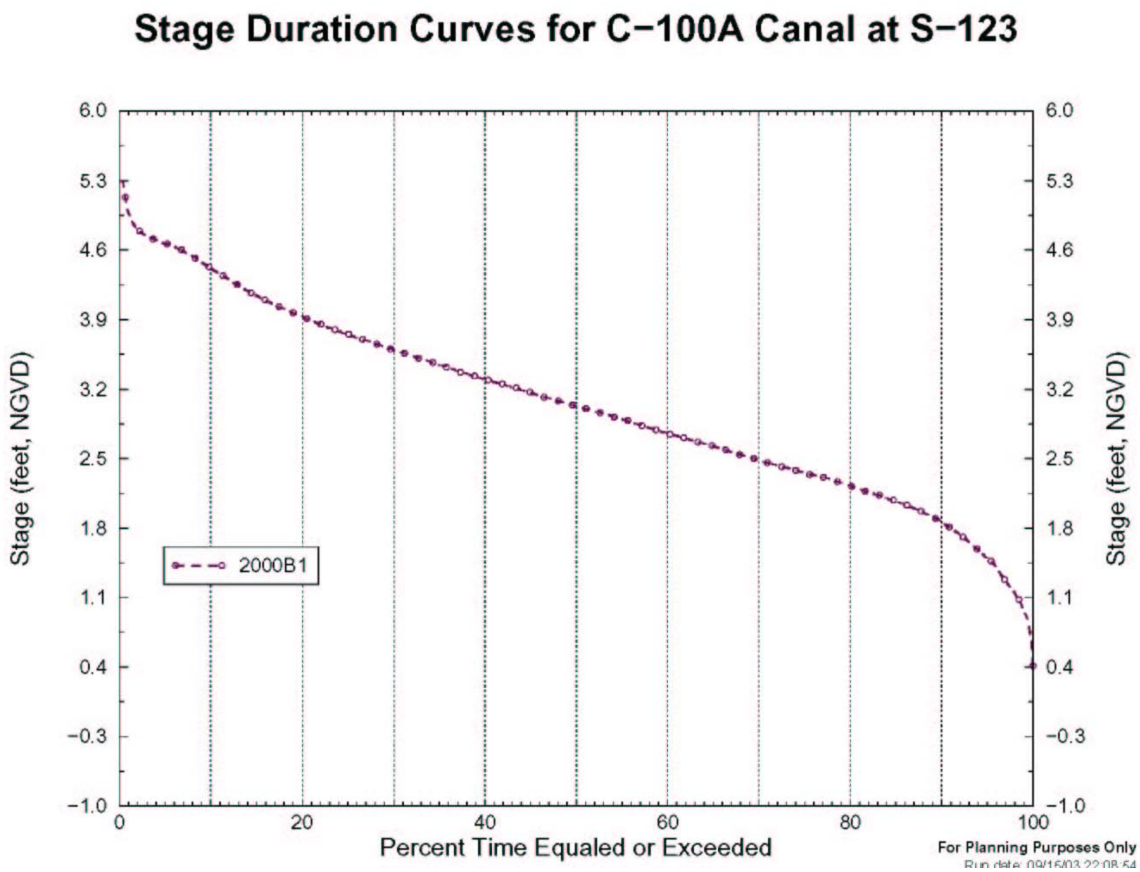



**Figure 18.** An example of a stage duration curve

If water is available, canals are maintained at these stages. During droughts and/or the dry season, there may not be enough water in the regional system to maintain these canal stages.

### How will we track whether the targets established for this indicator have been achieved?

The number of times (frequency) the coastal canal stage and the number of consecutive days (duration) the criterion is not met for each event will be analyzed to determine if it was related to drought conditions or other causes. The monitoring data will be compared to historical conditions and the ability to meet operating criteria.

### What additional work is needed to improve this interim target?

The canal stages need to be examined further to develop appropriate targets and operating criteria to prevent encroachment of the salt water into the surficial aquifer. This work is proposed in the Lower East Coast Regional Water Supply Plan (SFWMD 2000b) and development of minimum flows and levels for Southern Coastal Biscayne Aquifer and Biscayne Bay in 2004.

## References

SFWMD. 2000a. Minimum Flows and Levels for Lake Okeechobee, the Everglades and the Biscayne Aquifer. South Florida Water Management District, West Palm Beach, Florida.

SFWMD. 2000b. Lower East Coast Regional Water Supply Plan. South Florida Water Management District, West Palm Beach, Florida.

## INDICATOR T1.6 – FLOOD CONTROL: ROOT ZONE GROUNDWATER LEVELS IN THE SOUTH MIAMI-DADE AGRICULTURAL AREA EAST OF L-31N

### What is the target?

The target for this flood control indicator is maintain or improve the level of service of flood protection consistent with restoration.

### Why is this indicator important?

A goal of the CERP is to enhance economic values and social well being by maintaining or enhancing the current level of flood protection. By avoiding increased flood damages or mitigating for flood encroachment, increases to project and societal costs can be minimized.

### How will the interim target for this indicator be predicted?

A performance measure was developed for use during the C&SF Project Comprehensive Review Study, known as the Restudy, and was subsequently modified and adopted by the Regional Evaluation Team for use in CERP evaluations (RECOVER in prep.). This performance measure forms the basis for the development of this interim target.

**Flood Damage.** The South Florida Water Management Model (SFWMM) is used to simulate conditions at five-year intervals into the future. The SFWMM has limited capability to directly measure flood damage on individual fields or during relatively short events, but gives an indication of a change in flood risk caused by the operation of project features. Using a stage duration curve, the percentage of time the stage is above the root zone can be calculated and the information used to give an indication that there may be a flood control problem in the vicinity of a cell(s). The most important part of the stage duration curve is the range of higher stages. Differences occurring in the lower stages of the stage duration curve deeper than -2 feet are not important for predicting performance relative to this target.

Post processed model output data are 1) a stage duration curve for each indicator cell, or canal, where performance at the 1-20 percentiles are evaluated, and 2) a table that includes the following three groups of data: change in peak stage (feet) from the target; change in stage at the 10 percent duration line from the target; the difference between the alternative and target in duration that the water table is within 2 feet of ground surface.

**Flow Volumes.** Using the SFWMM to look at the flow volumes from the structures introducing water into south Miami-Dade County from the north gives an indication of the potential to overload the flood control capacity of the C-111 system.

Post-processed model output data will be a table containing wet season and dry season annual average flow volumes from G-211, S-331, S-173, S-334, S-335, S-357, and/or new structures included in the CERP projects added in the 5-year incremental model runs that introduce water into south Miami-Dade County.

### How will we track whether the targets established for this indicator have been achieved?

This interim target may be assessed by using parameters such as water stage, duration and frequency, and canal operating levels, flow volumes and timing.

### What additional work is needed to improve this interim target?

No additional work is needed at this time.

### References

RECOVER. In prep. CERP System-wide Performance Measures. Restoration Coordination and Verification, c/o South Florida Water Management District, West Palm Beach, Florida.

USACE and SFWMD. 1999. Central and Southern Florida Project Comprehensive Review Study Final Integrated Feasibility Report and Programmatic Environmental Impact Statement. United States Army Corps of Engineers, Jacksonville District, Jacksonville, Florida, and South Florida Water Management District, West Palm Beach, Florida.

## INDICATOR T1.7 – FLOOD CONTROL: GROUNDWATER STAGES FOR MIAMI-DADE, BROWARD, PALM BEACH AND SEMINOLE TRIBE SURFACE WATER MANAGEMENT BASINS

### What is the target?

Maintain or improve the level of service of flood protection consistent with restoration.

### Why is this indicator important?

A goal of the CERP is to enhance economic values and social well being by maintaining or enhancing the current level of flood protection. By avoiding increased flood damages or mitigating for flood encroachment, increases to project and societal costs can be minimized.

### How will the interim target for this indicator be predicted?

**Miami-Dade, Broward and Palm Beach Counties.** The Lower East Coast Sub-Regional Model (LECSR) is a new subregional model with a much finer scale than the South Florida Water Management Model (SFWMM) and with slightly different boundaries. It was developed by linking and improving existing county subregional models. Improvements consist of including new areas and using additional packages to the basic MODFLOW-96 model.

The LECSR will calculate average daily groundwater levels for each of the 5-year interim model runs subsequent to 2000. The LECSR can indicate whether changing hydrologic conditions have increased or reduced simulated peak stages as compared to the 2000 existing condition. The model should be used to compare relative differences between alternatives as opposed to absolute differences. For this exercise, the stage that is equaled or exceeded 5 percent of the time in the 36-year period of rainfall conditions from 1965 through 2000 will be used as the indicator of whether the frequency of high stages has been increased or reduced.

Post processed model output will be 1) a stage duration curve for each indicator cell, and 2) a table for each county/tribe comparing the baseline stages that were equaled or exceeded 5 percent of the time for each indicator cell.

**Seminole Tribe.** The SFWMM is used to calculate average daily groundwater levels for each of the 5-year interim model runs subsequent to 2000. The SFWMM has limited capability to directly measure flood damage during relatively short events, but gives an indication of a change in flood risk caused by the operation of project features. Using a stage duration curve, the percentage of time the stage is high can be calculated and the information used to give an indication that there may be a flood control problem in the vicinity of a cell(s). The most important part of the stage duration curve is the range of higher stages. Differences occurring in the lower stages of the stage duration curve deeper than -2 feet are not important for assessing performance relative to this target.

Post processed model output data will be 1) a stage duration curve for each indicator cell, or canal, where performance at the 1-20 percentiles are evaluated, and 2) a table that includes the following three groups of data: change in peak stage (feet) from the target; change in stage at the 10 percent duration line from the target; the difference between the alternative and target in duration that the water table is within 2 feet of ground surface.

### How will we track whether the targets established for this indicator have been achieved?

This interim target may be assessed by using parameters such as water stage, duration and frequency, and canal operating levels, flow volumes and timing.

### What additional work is needed to improve this interim target?

No additional work is needed at this time.

# INDICATOR T1.8 – FLOOD CONTROL: FLOOD WATER REMOVAL RATE FOR THE EVERGLADES AGRICULTURAL AREA

## What is the target?

Maintain or improve the level of service of flood protection consistent with restoration.

## Why is this indicator important?

A goal of the CERP is to enhance economic values and social well being by maintaining or enhancing the current level of flood protection. By avoiding increased flood damages or mitigating for flood encroachment, increases to project and societal costs can be minimized.

## How will the interim target for this indicator be predicted?

The South Florida Water Management Model (SFWMM) is used to simulate conditions for each of the five-year interim model runs subsequent to 2000. For this exercise, the output of structural discharge from the Everglades Agricultural Area in response to selected rain events will be compared with the same discharge from the 2000 existing condition.

Effective removal rate in response to significant rainfall events will be expressed in inches per day. This is computed by calculating the total pumping rate of the primary pumps serving the Everglades Agricultural Area following major storms divided by the number of acres being served by each pump. The same calculation can be made for the existing system to show the potential improvement available with the CERP. A series of indicator events is identified and the daily removal rate computed for each basin on each day during the pumping event. Higher removal rates in the days immediately following the heaviest rainfall and a shorter duration of total pumping would be possible indicators of improved performance.

Post processed model output will be summaries showing daily removal rate for significant rain events in the past. Time periods to be included in the summaries are as follows:

- 6/20/66 – 7/20/66
- 3/15/70 – 4/15/70
- 5/20/82 – 6/20/82
- 1/10/91 – 2/10/91
- 10/25/98 – 11/25/98

## How will we track whether the targets established for this indicator have been achieved?

This interim target may be assessed by using parameters such as water stage, duration and frequency, and canal operating levels, flow volumes and timing.

## What additional work is needed to improve this interim target?

This proposed interim target has been conceptually approved by the modelers, with the caveat that they will test run the performance of the metric once it is programmed before the use receives final approval.